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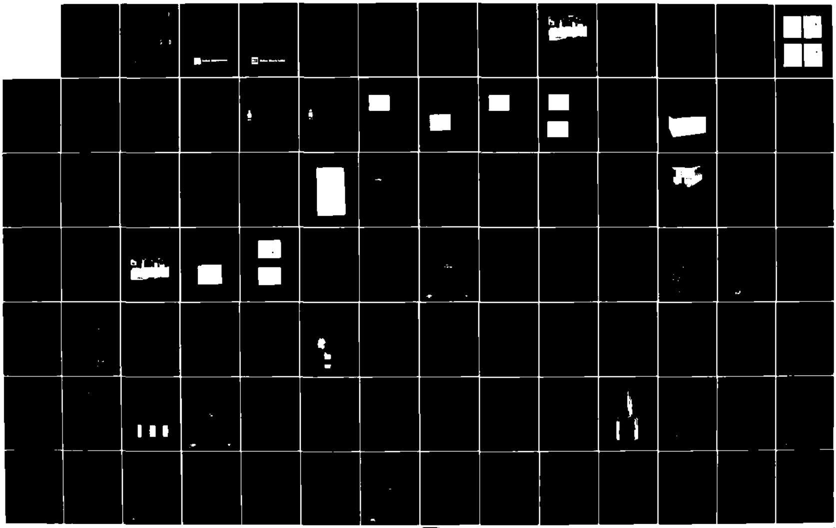

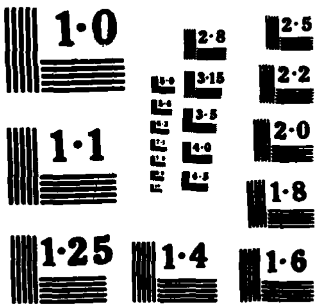
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October 1982

AD-A145 531

TECHNICAL REPORT

PROGRESS IN POWER DISTRIBUTION IN FISCAL YEAR 1982

Delco Electronics

General Motors Corporation
- Santa Barbara Operations
Santa Barbara, California

R82-127

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TECHNICAL REPORT

PROGRESS IN POWER DISTRIBUTION IN FISCAL YEAR 1982

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- Santa Barbara Operations
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SECTION I
INTRODUCTION

1.1 PURPOSE OF THIS TECHNICAL REPORT

This publication is a report on accomplishments in the area of power distribution made in Fiscal Year 1982. These include:

1. Development and demonstration of a touch screen CRT controller for power distribution control, including paralleling.
2. Development and demonstration of the use of fiber optics for such control.
3. Further reduction in the input current harmonics in the 15 kW Frequency Changer, which uses the Delco Resonant AC-DC Converter.
4. Demonstration of the great tolerance to non-linear loads inherent in the 28-SCR Delco Inverter.

1.2 BACKGROUND

The equipment necessary to meet the FY82 objectives was all designed and, with the exception of the touch screen CRT equipment, fabricated prior to FY82. Some of the equipment was modified and the touch screen equipment was completed within the last year.

This report is organized so that limited background for the various pieces of equipment and some detailed information on modifications are presented in following sections. One section generally deals with one piece of equipment. Also, complete sets of schematic diagrams and some pictures are found in appendices.

In 1980, Delco published a report* which presented general power network control concepts and some specifics on hardware implementation. Many of the details of hardware implementation in this report should be reconsidered in

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* Microprocessor Control of Frequency Changers and Power Distribution Systems. Technical Report R80-119. Delco Electronics Division, GM. (3 October 1980)

light of the work performed since then and to date. Another report on this subject of more recent value was included in Delco's IR&D Technical Plan for 1982. A copy of this IR&D project is provided in Appendix A.

1.3 SYSTEM OVERVIEW

By using Government loaned equipment (GLP), the Distribution Unit (formerly called the Paralleling Controller), the 15 kW Frequency Changer, and the 10 kW Firefinder Generator Set (a test bed unit) - combined with a touch screen controller built on IR&D funds, it has been possible, with a relatively low expenditure of money and time, to set up a simple yet comprehensive demonstration. In order to maximize accomplishments and reduce risk to the GLP equipment, the objective of minimizing changes to the GLP equipment was set and rigidly observed. This meant that hardware packaging and many performance features of the various pieces of equipment had to be compromised. Thus, the system and its components are far from what Delco views as highly desirable. Nevertheless, by judicious limitation of the scope of the demonstration to the essentials, comprehensive coverage of major performance features has been achieved.

Paralleling is restricted to two power sources, one functioning as a master and the other as a slave. As such the master cannot be controlled in the demonstration in either output amplitude or frequency. It falls into a broad category of sources - such as the power utility, a motor-generator set, an engine driven generator set, or another frequency changer.

For the demonstration, a 10 kW Firefinder Set was chosen as the master. The slave, then, must be controllable in output amplitude and frequency. In fact, the slave must be capable of phase lock to the load power bus. Further, the slave must be able to track the load power bus in amplitude.

Figure 1-1 shows the laboratory set up of the demonstration. Figure 1-2 is a block diagram of the interconnection of the various pieces of equipment. This set up is dealt with in more detail in Section V.

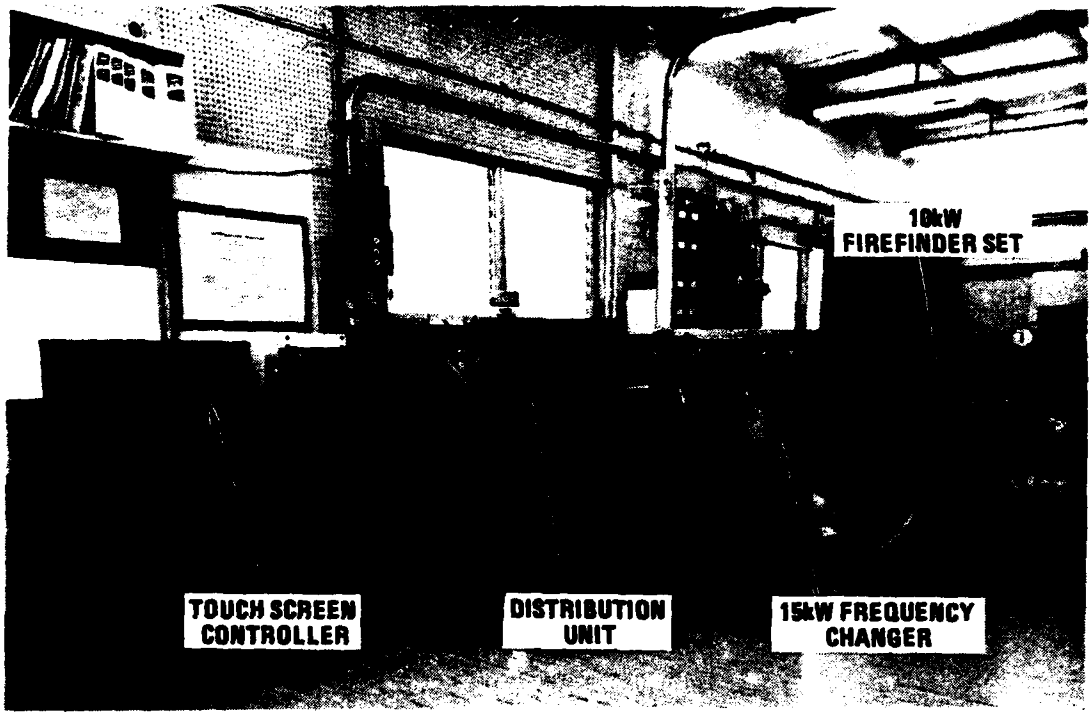


Figure 1-1. Laboratory Setup of Demonstration

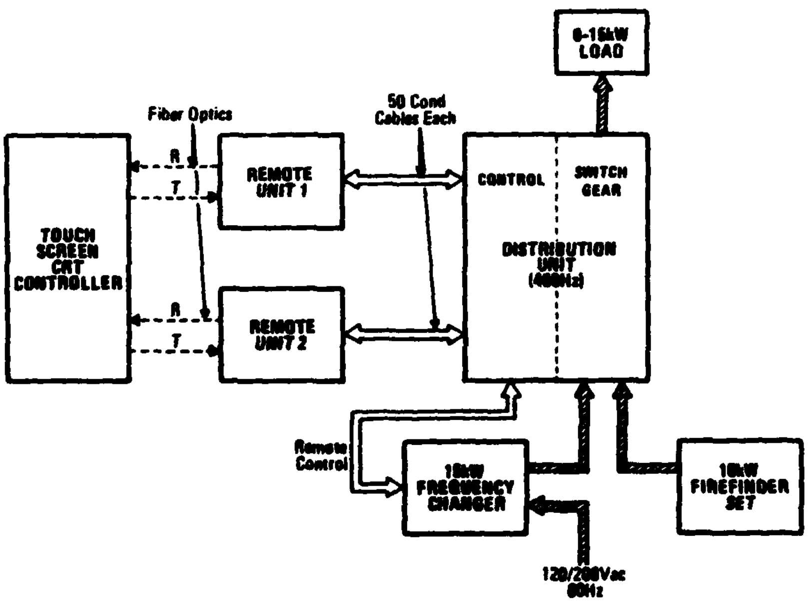


Figure 1-2. Interconnection Diagram of Laboratory Demonstration Setup

Although it is felt by Delco Electronics that phase locking and amplitude tracking features should be an integral part of each frequency changer, the GLP 15 kW unit, being developmental, lacked them. Thus for expediency the control loops necessary for these features were actually mechanized in the Distribution Unit. To further limit the scope to essentials, these loops were made to function at 400 Hz only.

In order to demonstrate touch screen CRT control and monitoring, yet introduce a minimum of changes to the GLP Distribution Unit, analog I/O were added to it. To demonstrate fiber optics using serial digital communications, however, it was necessary to convert analog to serial digital with fiber optic drivers/receivers. This was accomplished with the design and construction of two microprocessor controlled Remote Units completed in FY82. Again, this was done as an expedient and not because Delco Electronics feels this is the best approach. It is felt that Distribution Units should be able to communicate with both the touch screen controller and the power sources through serial digital fiber optic communication ports.

For expediency, the touch screen CRT Controller, constructed in FY82, was designed to be able to handle only one Distribution Unit. This controller is entirely digital and uses one microprocessor for touch screen CRT control and a second for communications and processing. Data and commands in serial digital format are sent between the Remote Units and the touch screen CRT controller over fiber optic "wires". The system adequately demonstrates the use of fiber optics. It is felt that a touch screen CRT controller should be configured in the future to drive not only one but several distribution units and/or power sources.

Although the touch screen CRT Controller is rather simple, both in hardware and software, it demonstrates many of the features Delco feels a power network system controller should have. These features are:

1. Friendly, prompted control of power sources and loads
2. Simple, inexpensive and reliable fiber optic communications
3. Source and load performance monitoring
4. Malfunction displays.

Additional features which would be highly desirable are as follows:

1. Logging of performance history with non-volatile storage
2. Programmed automatic network reconfiguration and load control (for optimum energy usage, highest reliability, system fault tolerance, etc.)
3. System diagnostic display
4. Automatic power network test
5. Operator self-instruction
6. Time standard frequency reference (for accurate time keeping).

The following material in the section describes in summary form the major accomplishments of the demonstration of FY82 and some of the performance features of the equipment used. Later sections and appendices provide more detail.

1.4 HIGHLIGHTS OF FISCAL YEAR 1982 ACCOMPLISHMENTS

This section is provided to very briefly point out some of the most noteworthy accomplishments of the FY82. Some of the most impressive resulting data are provided. The largest portion of the work reported here deals specifically with the Touch Screen CRT Controller and fiber optics used to demonstrate power distribution network control. For this demonstration Delco utilized the following:

1. **Microcomputers** - Eight-bit microprocessors based on the Motorola 6800 family, and 16-bit microprocessors based on the Intel 8086 family with attendant memory, A/D, and I/O chips; system configurations employing distributed processing and co-processing serial communications techniques.
2. **Fiber Optics** - Communication links to route multiplexed serial data between microcomputers and systems; high data rate, EMI-proof, rugged, low cost.
3. **"Touch Screen CRT"** - Simple, compact means to eliminate all mechanical switches and controls and dedicated individual displays; all displays and control functions combined in a ruggedized small screen CRT with a touch sensitive face; totally flexible display format of

alphanumerics and graphics; self-prompting, easy to understand presentation formats.

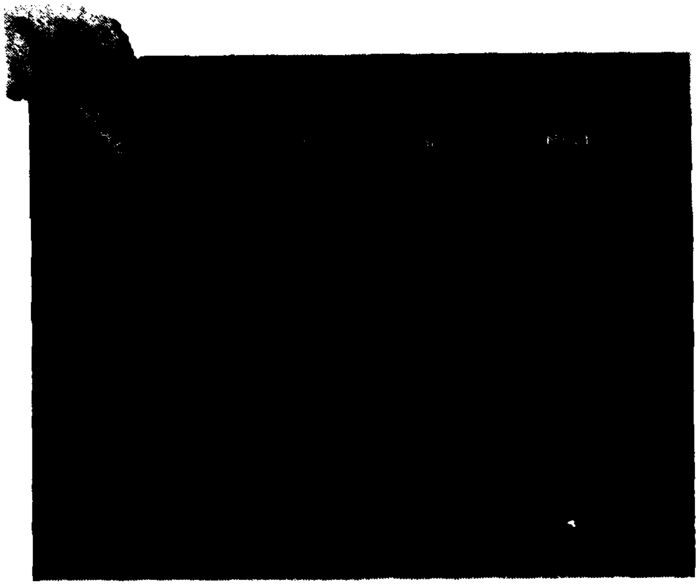
4. **"Hardened Design Techniques"** - Specific circuit and system designs address EMI/RFI, fail-safe, fail-soft with backup, hardware and software self-test, and constantly running system diagnostics.

This work was relatively hardware rather than software intensive. It was felt that with the limited funds available for the effort only enough software to demonstrate the real potential of the touch screen would be written. Accordingly, the software for four simple screen displays was written. The four different screen displays are shown in Figure 1-3.

The initial display is the summary screen shown in the upper left corner. This display may be selected at any time by simply touching the word SUMMARY as shown. The Summary screen is used for information display only. It demonstrates the use of a single screen to display complete status. Should there be a system malfunction, a message to that effect would appear in the lower right hand corner of the Summary screen. This is also true in the case of Unit 1 or Unit 2 screens. To determine the nature of the malfunction the operator touches the letters MALF. The Malfunction screen then displays the nature of the malfunction. At present, a communications error to Unit 1 and/or Unit 2 is/are the only malfunction(s) reported.

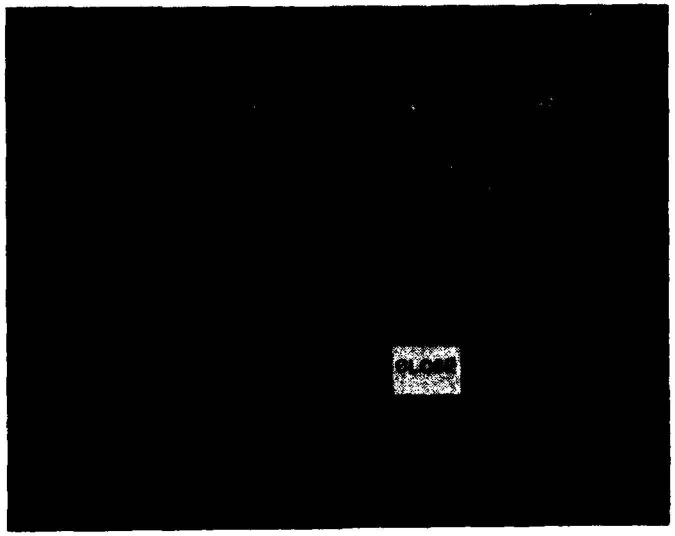
The Unit 1 screen, selected by touching the letters UNIT 1, demonstrates the use of the touch screen to provide software selectable switches. If the master source's contactor is to be opened or closed, this is accomplished by touching the appropriate word OPEN or CLOSE. The use of reverse video, as shown by the word CLOSE, and a single audible beep indicates the action was taken. Thus reverse video is used much like a pilot light.

The Unit 2 screen demonstrates the use of the touch screen to provide software selectable potentiometers. For example, if it is desired to increase the amount of power the slave source (Unit 2) contributes to the power bus, the letters INCR are touched. There is a beep and the block including INCR is displayed in reverse video for approximately one second. This causes a single

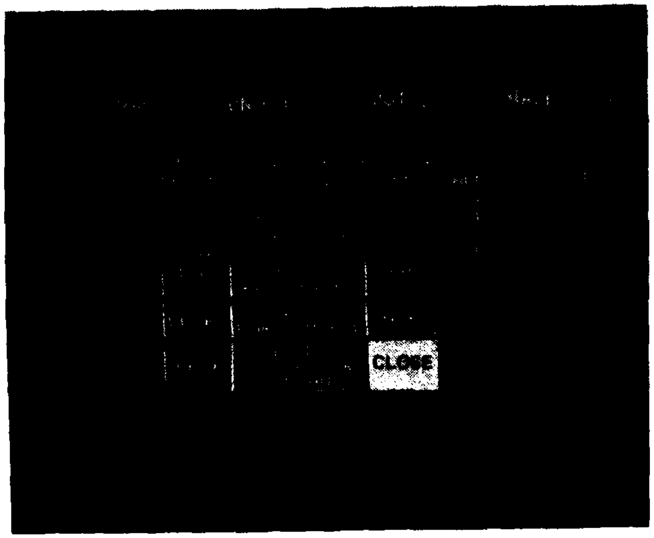


a. Typical Summary Screen

b. Typical Malfunction Screen



c. Typical Unit 1 Screen



d. Typical Unit 2 Screen

Figure 1-3. Touch Screen Display

step change in increased power output. If this is insufficient, additional steps may be entered at the rate of about one per second.

The touch screen CRT hardware was built and the software debugged. The equipment very effectively demonstrates the use and potential value of the touch screen concept.

Another noteworthy aspect of this development is the use of fiber optics as the sole communications link to the touch screen controller. The mechanization involves four fiber optic "wires". Unit 1 communications and control are handled by one "wire" for transmit and a second for receive. Unit 2 has a corresponding pair. This approach works very well and may be readily adapted to commercial standard RS 232C serial communications or Military Standard 1553 serial communications rates and protocol.

An important use for the touch screen controller is control of paralleling of a power system consisting of two sources. This might be more correctly called remote control of paralleling since the actual controlling is done in hardware other than that of the touch screen controller. Paralleling control is accomplished in the Distribution Unit. In FY82, work was done on this unit to improve its performance relative to paralleling.

Figure 1-4 shows the results of a rapid transfer of power sources from the master (10 kW Firefinder GTE generator set) to the slave (15 kW Frequency Changer). In mechanical switching terminology, this is called make-before-break switching. It is particularly significant here that the slave source at all times before, during, and after the transfer is tracking the master source in output frequency, phase, and amplitude. Thus the transfer is transient free with respect to the nature of the power to the load.

This no break rapid transfer was demonstrated in transfers from master-to-source and source-to-master. Furthermore, slow transfers involving a variable length period of paralleling were also demonstrated. Results were always clean with no break in the power to the load. This performance in transfer operations is mandatory for multi-source power distribution systems and networks of the future.

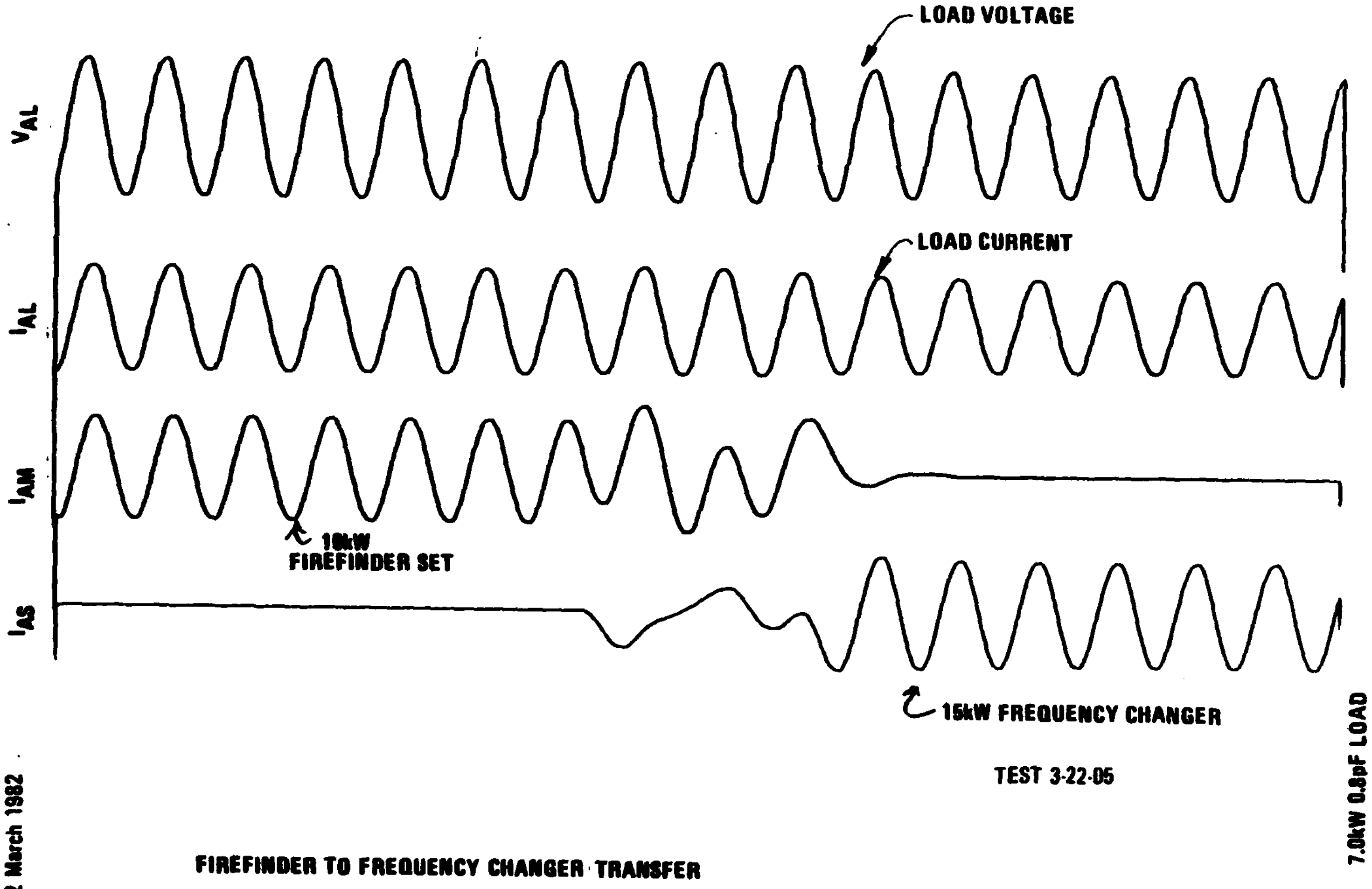


Figure 1-4. Rapid Power Transfer Performance

Figure 1-5 shows the phase response of the slave unit to a quasi-step change in master frequency. Note the response is rapid and has no overshoot. This response characteristic is very adequate for any distribution system where the master is an engine or motor driven alternator and where frequency transients could occur. A considerable amount of testing was performed with both amplitude and frequency transients. The performance in all cases was completely adequate for general distribution systems.

Work was done with both the converter and inverter portions of the 15 kW Frequency Changer to improve and characterize its performance in stand alone, as well as distribution, use. The input filter of the 15 kW Frequency Changer was improved with the addition of three capacitors and three inductors so that its input power factor was improved and its input current harmonic generation was reduced. Also, its output voltage waveform (more exactly that of a 10 kW Firefinder GTE generator set with a similar 28-SCR inverter) was recorded with several typical nonlinear load configurations.

Figure 1-6 is a plot of the typical total harmonic distortion (THD), contribution of the 3rd through 13th harmonics and the 5th harmonic of the input currents to the 15 kW Frequency Changer over a wide operating range. These data are taken with the unimproved input filter developed prior to FY82. While this performance is impressive, it does not meet Navy requirements which limit the amplitude of individual harmonics to 3%.

Figure 1-7 is a plot of the same thing except that the input filter improvements of FY82 have been made. Observe that these data meet Navy requirements. It is felt that minor changes in the input filter could reduce the peak of nearly 5% in the THD curve. (This peak is not actually due to distortion which is a harmonic of the 60 Hz input lines, but rather conducted harmonics related to the converter operating frequency.)

Figure 1-8 shows typical input voltage waveform and current at approximately rated input. These results, which indicate the feasibility of producing power supplies which meet Army as well as Navy specifications for input harmonics, are extremely gratifying. As far as known, the Delco approach to harmonic

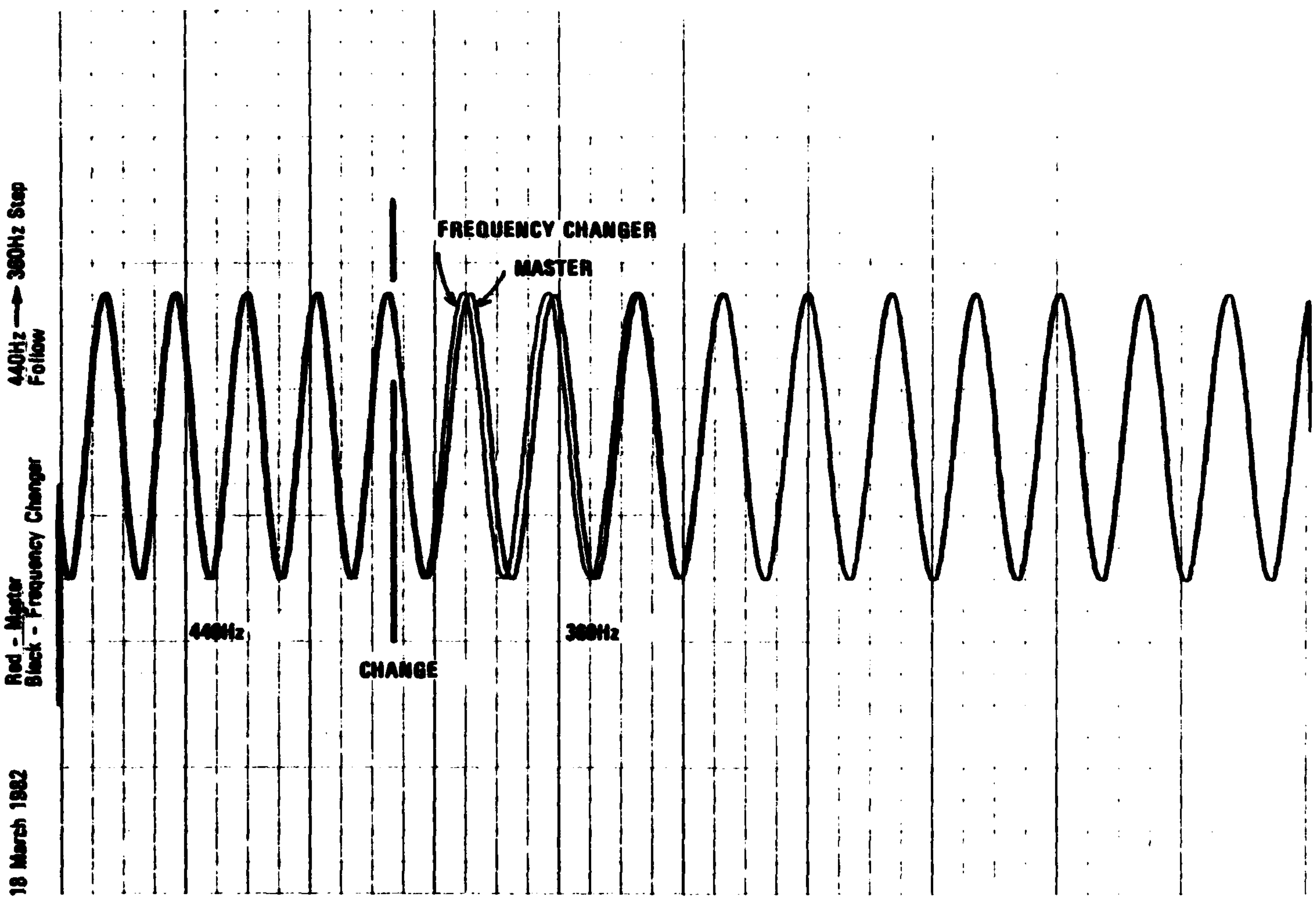


Figure 1-5. Effect of Step Change in Reference Frequency on Phase Lock

EQUIP 15KW FREQ CHGR

MFGR DELCO

MODEL NO.

SERIAL NO.

REF:

SANTA BARBARA, CALIFORNIA

TEST NO. SEE TEST REC

DATE MARCH 01, 1982

BY

TEST REC 01-03-01

THROUGH 01-03-08

ORIGINAL

INPUT FILTER

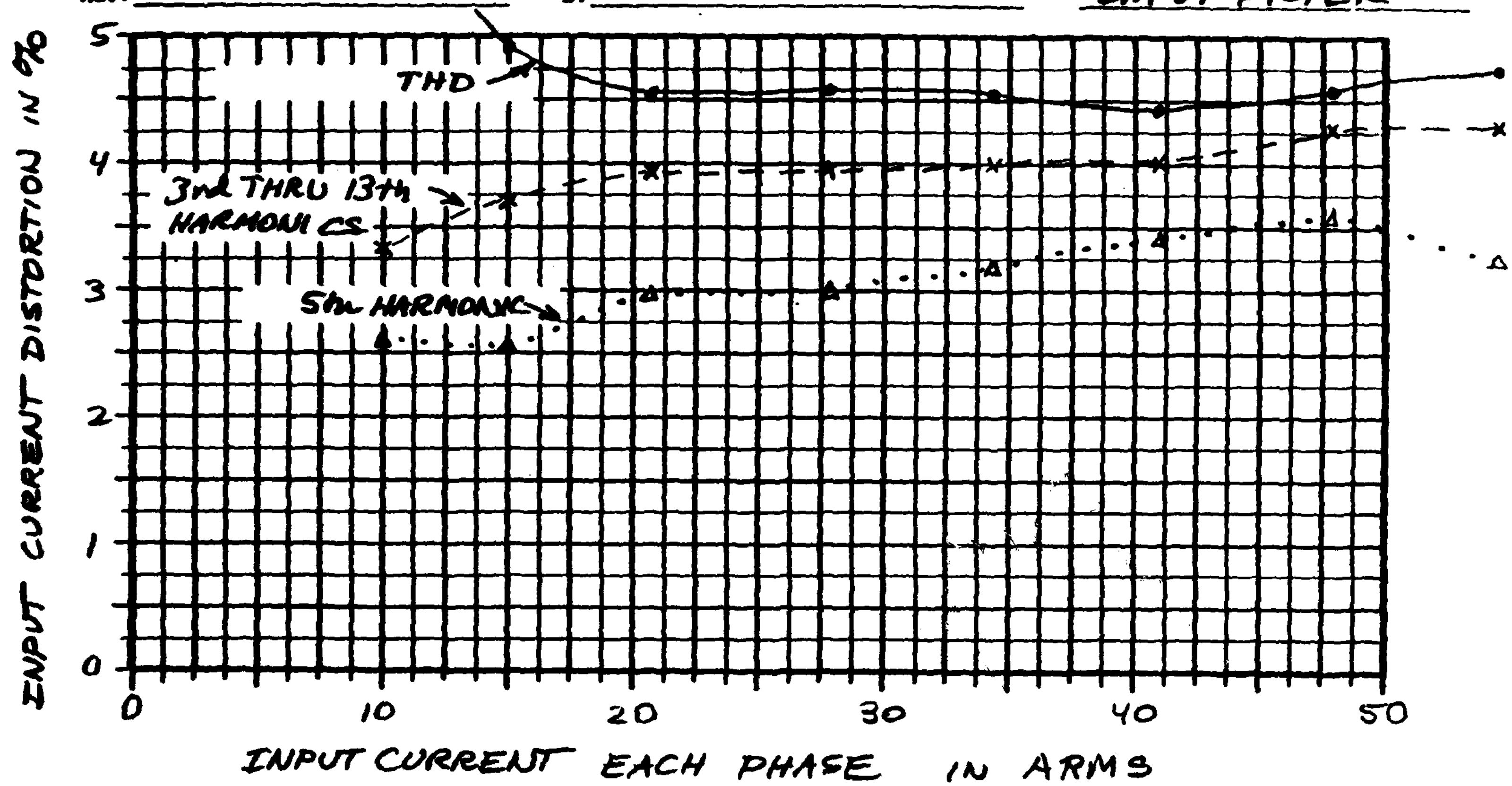


Figure 1-6. Typical Harmonic Distortion Contribution

EQUIP 15KW FREQ CHGR

MFGR DELCO

MODEL NO.

SERIAL NO.

REF:

SANTA BARBARA, CALIFORNIA

TEST NO. SEE TEST REC

DATE MAY 24 & 25 1982

BY

TEST REC 24-5-01

& 25-5-01

AUGMENTED

INPUT FILTER

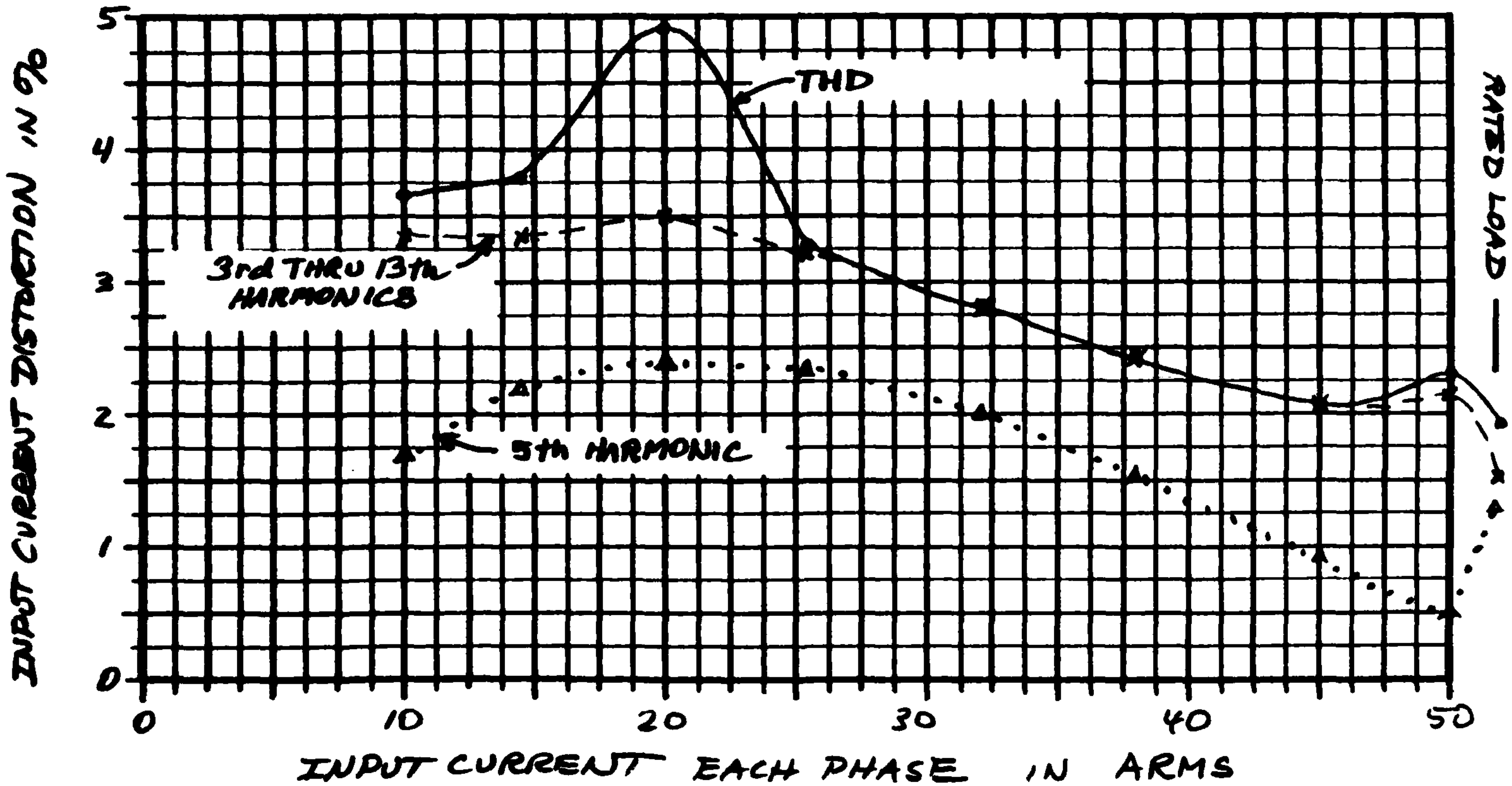
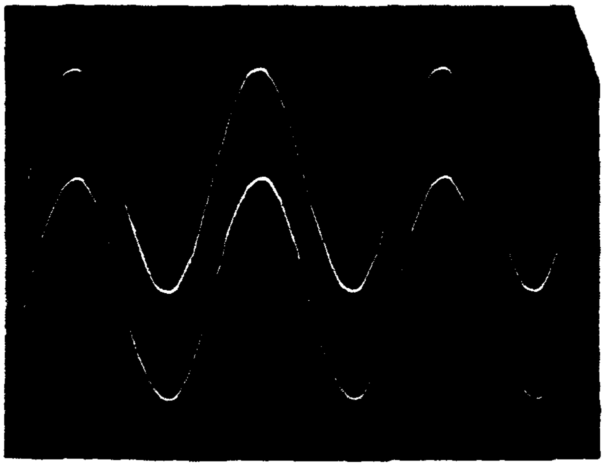


Figure 1-7. Harmonic Distortion Contribution After Input Filter Improvement



TEST DESCRIPTION L-N VOLTAGE & CURRENT WAVEFORMS

V1 VØA L-N THD=1.22%

V2 IØA THD= 2.32%

V3 CONVERTER INPUT

V4 POWER = 19 KW

H1

H2

TEST NO.

PIX NO. /

Figure 1-8. Typical Voltage and Current Waveforms at Approximately Rated Input

reduction is the only one which is passive, does not use multiphase rectification or large passive filters and yet meets these specifications. While it has been shown by Delco and others that another approach using active (feedback) control can achieve similarly low levels of harmonic generation, this approach lacks the simplicity, reliability and inherent stability of the Delco passive approach.

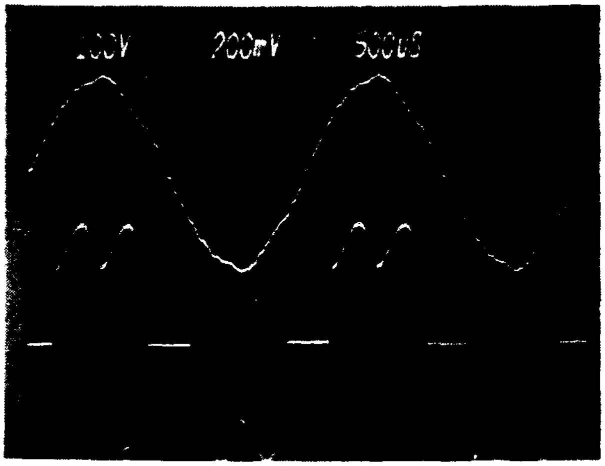
Implementation of the Delco passive harmonic reduction technique in the power supplies of load equipment should be a highly effective way of cleaning up the power to this load equipment and other equipment on the same distribution system.

Another highly effective approach to having clean power distribution is to use a power source which is less susceptible to degradation by conventional equipment power supplies than the alternators which are often used. Figure 1-9 and Figure 1-10 illustrate this approach with a 10 kW non-linear load simulating typical power supplies. They show the efficacy of the Delco 28-SCR inverter in this approach. Note that voltage waveform distortion - which causes problems with sensitive loads - is approximately 12 percent with the alternator and only about 3.5 percent with the Delco 28-SCR inverter. Furthermore, high order harmonics, which are especially troublesome, do not appear as high in amplitude with the Delco inverter.

TEST DESCRIPTION

V1 VØA 100V/DIV
V2 IØA 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 17-06-05
PIX NO. 1

Figure 1-9. Waveforms Which Result When A Typical Power Supply Load Is Applied to a 12.5 kVA Alternator Driven Bus

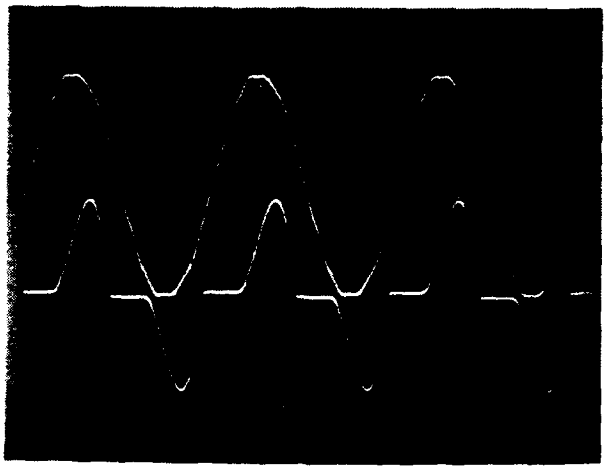


TEST DESCRIPTION ______

V1 VØA 100V/DIV
V2 IØA 20A/DIV
V3
V4
H1 1KHz/DIV
H2
TEST NO. 17-06-03
PIX NO. 1

Figure 1-10. Waveforms Which Result When The Load of Figure 1-9 Is Applied To The Delco 28-SCR Inverter

Figure 1-11 and Figure 1-12 show the results of applying, respectively, a 9 kW load simulating a different type of power supply configuration and a 6 kW load simulating still a different configuration to the Delco inverter. These results show remarkably high waveform purity with conventional power supply loads and meet precise classes of military requirements. Most other types of inverters use feedback in the generation of their output waveforms and are prone to having severely degraded or unstable output into typical power supply loads. The Delco 28-SCR inverter, which has no such feedback, experiences no difficulty in driving power supply loads. It even drives pulsed power supply loads.



TEST DESCRIPTION VØx L-N & IØx WAVEFORMS

V1 VØA L-N THD=2.46%

V2 IØA THD=45.5%

V3

V4

H1 5MS/DIV

H2

TEST NO. 24-5-04

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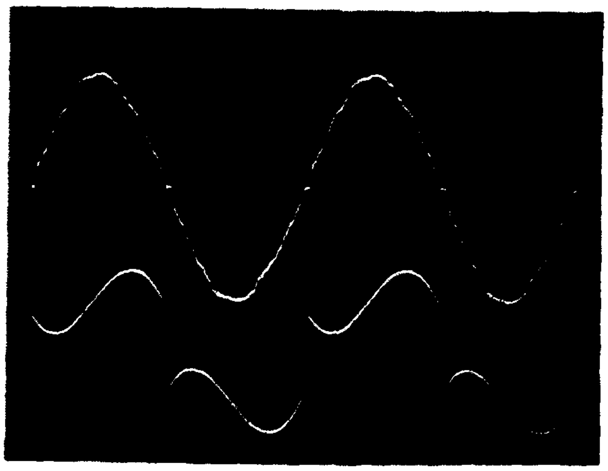
Figure 1-11. Delco Inverter Driving A Second Type Of Power Supply Load at 9 kW Output



TEST DESCRIPTION VØx L-N & IØx WAVEFORMS

V1 VØA L-N THD= 2.98%

V2 IØA THD= 36.9%

V3

V4

H1 500µs/DIV

H2

TEST NO. 24-5-05

PIX NO.

Figure 1-12. Delco Inverter Driving A Third Type Of Power Supply Load At 6 kW Output

SECTION II

TOUCH SCREEN CRT CONTROLLER AND REMOTE UNITS

2.1 BACKGROUND

This effort represents the first application by Delco of either microprocessor or touch screen technology to the area of control of power distribution systems. In the automotive area, however, applications have been extensive.

In 1975, Delco began development of the General Motors Custom Microcomputer (GMCM). In 1979, the GMCM was used in General Motors first production microcomputer engine control. By 1981, all GM passenger cars used one or more GMCM chip sets. Additional applications have been found in multifunction engine controls, transmission controls and other vehicles.

The microcomputer, GMCM and others, are now found in GM electronically tuned radios, electronic climate controllers, fuel, range, and trip computers, digital speedometers and gauges, and computer controlled memory seats. Much of the original application work in this automotive area was done by Delco Electronics - Santa Barbara Operations. Thus, the application of microcomputers to power distribution was easily and successfully made.

Touch screen CRT's have been under development by Delco since 1979. These units have instrument panel applications in GM cars of the future. To date, a number of engineering feasibility units have been built and tested.

Automotive applications for both technologies require high reliability and ruggedness because the automobile is a very harsh environment. Success in this regard indicates high potential for use of these technologies in the area of military power distribution control.

2.2 FUNCTIONAL DESIGN OF THE TOUCH SCREEN CRT CONTROLLER

The Touch Screen CRT Controller is designed to control and receive data from the Distribution Unit by fiber optic "wires". Rather than provide fiber optic communictions directly from the Distribution Unit - which would have required very extensive modification of the same - fiber optic communications are handled by external interface units called Remote Units. The Remote Units then may be viewed as adapters which give the Distribution Unit the necessary fiber optic communications ports. Figure 2-1 shows the Touch Screen CRT Controller. Figure 2-2 shows the mechanization of both the Touch Screen Controller and the Remote Units. Figure 2-3 is a block diagram of the Touch Screen CRT Controller.

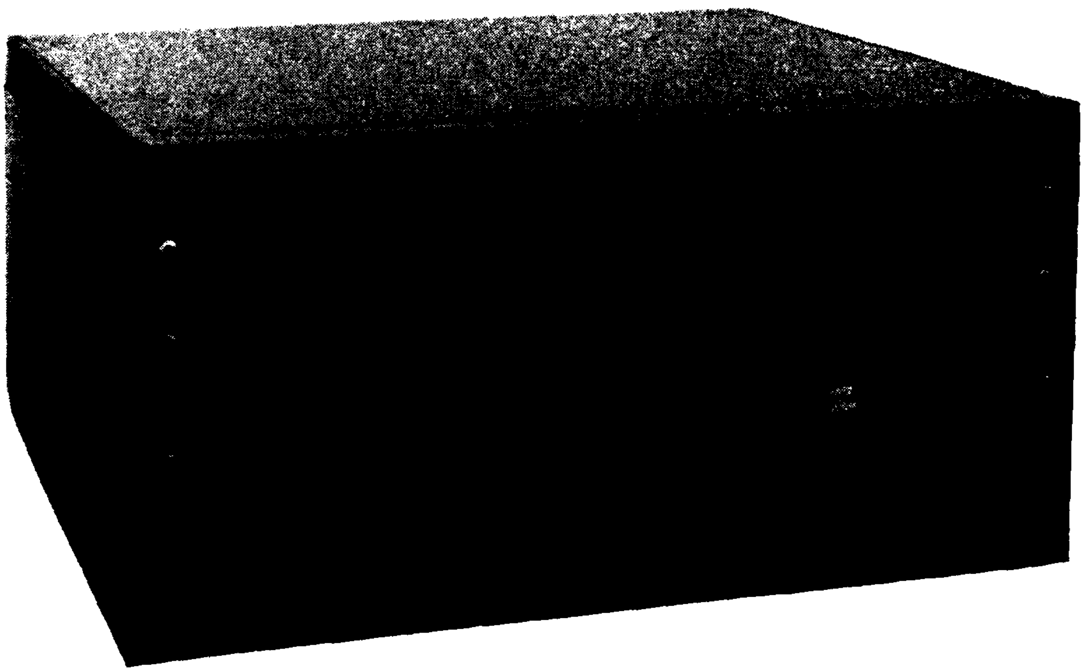


Figure 2-1. Touch Screen CRT Controller

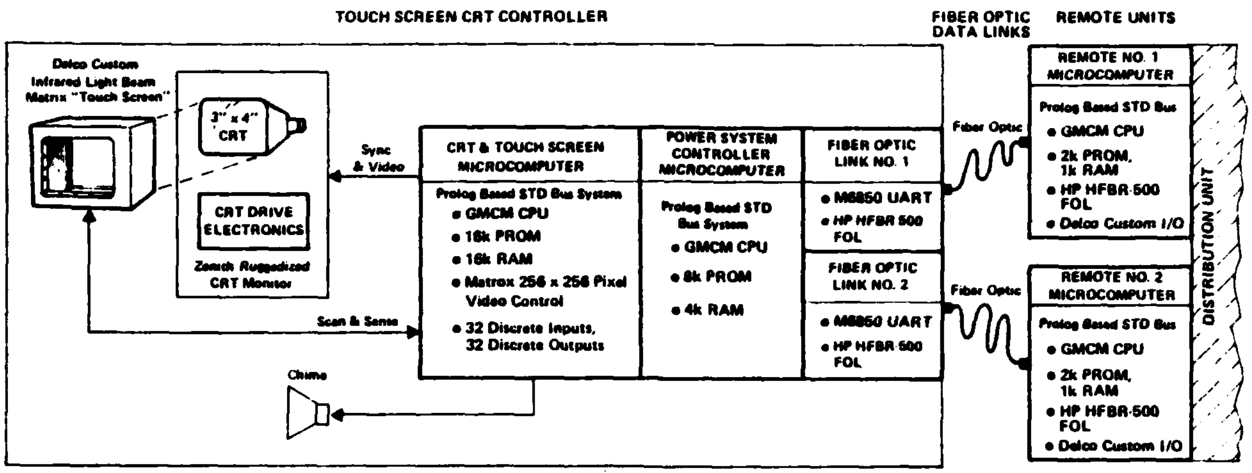


Figure 2-2. Touch Screen CRT Controller and Remote Unit Mechanization

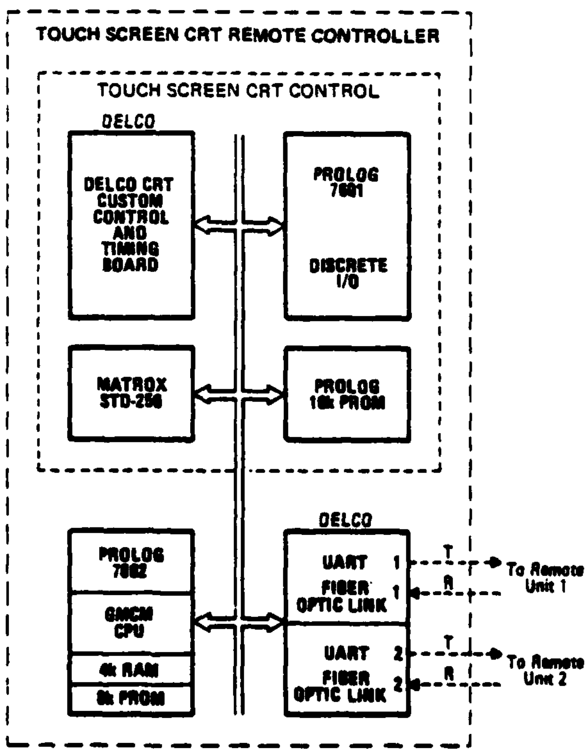


Figure 2-3. Block Diagram of Touch Screen Controller

A matrix of infrared emitters and detectors is placed in front of the CRT. When a finger is brought directly up close to the screen horizontally and vertically, IR light beams are broken. With this approach, it is possible to determine if and where a command is being entered by the operator. Thus, the screen may be considered to be an array of switches which may be identified and reconfigured with software. A chime with a single beep is used to inform the operator that he has "thrown a switch". The CRT is driven by deflection electronics supplied by Zenith. Screen size is 3 inches by 4 inches with bright yellow phosphor against a black background.

Screen presentation is in the form of a bit map. The pixel matrix size is 256 by 256. The video controller for the bit map is supplied by Matrox. The CRT presentation and the touch screen are controlled by a microcomputer as in Figure 2-3. This microcomputer is configured in a Prolog CCA using the Prolog standard bus. The microprocessor used is the General Motors Custom Microprocessor (GMCM) which is a derivative of the Motorola 6800 family. The memory on this bus is 16k bits of programmable read only memory (PROM) and 16k bits of random access memory (RAM).

In an effort to minimize software development heavy usage is made of algorithms and software which had already been written for automotive applications. Actual displays and software controlled touch screen switches are in software unique to the power distribution control application.

The Prolog standard bus is extended to include a second microcomputer which is dedicated to data processing and communications with the Remote Units. This microcomputer is also configured with a GMCM microprocessor and uses 8k of PROM and 4k of RAM. This microprocessor receives the following data at an update rate of approximately one per second:

1. From Unit 1
   - VMΦA, VMΦB, VMΦC (voltage master phase A, etc.)
   - IMΦA, IMΦB, IMΦC
   - PMΦA, PMΦB, PMΦC
   - ΦMA (power factor (PF)) sign bit
   - ΦMB sign bit
   - ΦMC sign bit

2. From Unit 2
   - VSΦA, VSΦB, VSΦC
   - ISΦA, ISΦB, ISΦC
   - PSΦA, PSΦB, PSΦC
   - ΦSA sign bit
   - ΦSB sign bit
   - ΦSC sign bit

With this data the microcomputer is used to calculate the following:

1. For Unit 1
   - VM average
   - IM average
   - PM total
   - IM total
   - PFMΦA incl sign
   - PFMΦB incl sign
   - PFMΦC incl sign
   - PFM average

2. For Unit 2
   - VS average
   - IS average
   - PS total
   - IS total
   - PFSΦA incl sign
   - PFSΦB incl sign
   - PFSΦC incl sign
   - PFS average

Power factor is determined by dividing the power by the volt-ampere product (e.g. PFMΦA = PMΦA/[VMΦA x IMΦA]).

This second microcomputer communicates with the Remote Units through fiber optic "wires" - a total of two for transmit and two for receive. To accomplish this two universal assynchronous receiver transmitters (UART) are used to convert serial to 8 bit parallel. These UART's are operated at a 9600 baud data rate.

2.3 FUNCTIONAL DESIGN OF THE REMOTE UNITS

Each Remote Unit, shown in block form in Figure 2-4, uses a microcomputer for communications control. A UART, again operating at a 9600 baud data rate, is used at the fiber optic interface. The microcomputer uses a GMCM microprocessor with 2k of PROM and 1k of RAM.

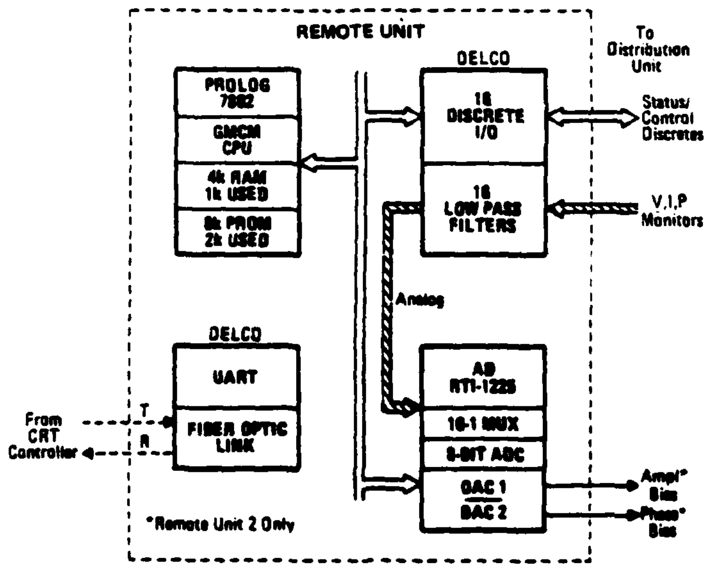


Figure 2-4. Block Diagram of Typical Remote Unit - One of Two

The microcomputer in each Remote Unit operates with a 16 to 1 analog multiplexer (MUX) and are analog-to-digital converter for communicating voltage, current, and power signals. These signals, which are scaled average values, are filtered with low pass filters ahead of the MUX.

In addition to these monitored signals, which the microcomputer communicates to the touch screen CRT controller, the microcomputer also issues command discretes to the Distribution Unit and issues status discretes to the touch screen CRT controller. Remote Unit 1 is configured in terms of hardware and software the same as Remote Unit 2. The distribution Unit uses the two digital-to-analog converters (DAC) of Remote Unit 2 for amplitude and bias control. The outputs of the DAC's in Remote Unit 1 are unused. (The Remote Units may be interchanged.)

2.4 CHARACTERISTICS OF FIBER OPTIC LINKS

In order to keep cost down an inexpensive commercial grade fiber optic link (FOL) was chosen. The components used belong to the Hewlett-Packard HFBR-0500 series. This series uses plastic snapin connectors and operation is limited to five meters. The data rate capability is dc to 5M baud. Delco is using five meter cables and maximum data rate of 9.6k baud.

Delco has not done a survey to find the most suitable fiber optic components for military applications. However, such components are presently available. For commercial applications Hewlett Packard makes components which will operate over a temperature range of -20°C to +70°C. They are useful up to 1,000 meters at a 10M baud data rate.

Fiber optic data communications offer many advantages for military applications. Very high data rates are possible at low cost. As the cables are non-conductive they may safely be located close to power lines (even in the same conduits). They offer high security because they are EMI proof and radiate no electromagnetic energy. The cables are lightweight and easy to install.

2.5 HARDWARE DESIGN AND IMPLEMENTATION

The Touch Screen CRT Controller and the Remote Units are housed in low cost commercially available cabinets, since early in the development cycle it was felt unwise to design military type cabinets - expecially with immature electronics designs. Commercial power supplies and Prolog card cages were used to reduce development costs.

Photographs and schematic diagrams of the Touch Screen CRT Controller are found in Appendix K. Photographs and schematic diagrams of the Remote Units are found in Appendix L.

SECTION III
DISTRIBUTION CENTER

3.1 BACKGROUND

Development of the Distribution Center (formerly referred to as the Paralleling Controller) began in 1980 as part of the 15 kW General Purpose Frequency Changer Performance Improvement Program. In March 1981, Delco published a report* describing this Distribution Center and its use. The Distribution Center was built in 1980 to function with the 15 kW Frequency Changer and permit its paralleling with other power sources. This Distribution Center constituted the entire operator interface for paralleling, which was controlled on the front panel with switches and potentiometers.

3.2 EFFORT FOR FY82

The FY82 IR&D objective was to incorporate a Delco touch screen CRT controller in the paralleling demonstration. This was accomplished by modifying the Distribution Unit furnished as GLP. Although the modification was rather extensive, it was the most expedient way to accomplish the stated objective.

Figure 3-1 is an external view of the Distribution Center. Since all the modifications made in 1982 were internal, none are apparent in the picture. The following features of the design were changed by the 1982 modifications.

1. The phase locking circuitry has component values for 400 Hz operation. (As such, it may not function properly at 50 or 60 Hz.)
2. The power limit and power sharing features and their control potentiometers are disabled.
3. The Single Port mode should not be used.
4. The Distribution Unit must always be used with the Remote Units and the CRT Controller.

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* 15 kW General Purpose Frequency Changer Performance Improvement. Technical Report R81-31. Delco Electronics Division, General Motors. (March 12, 1981)

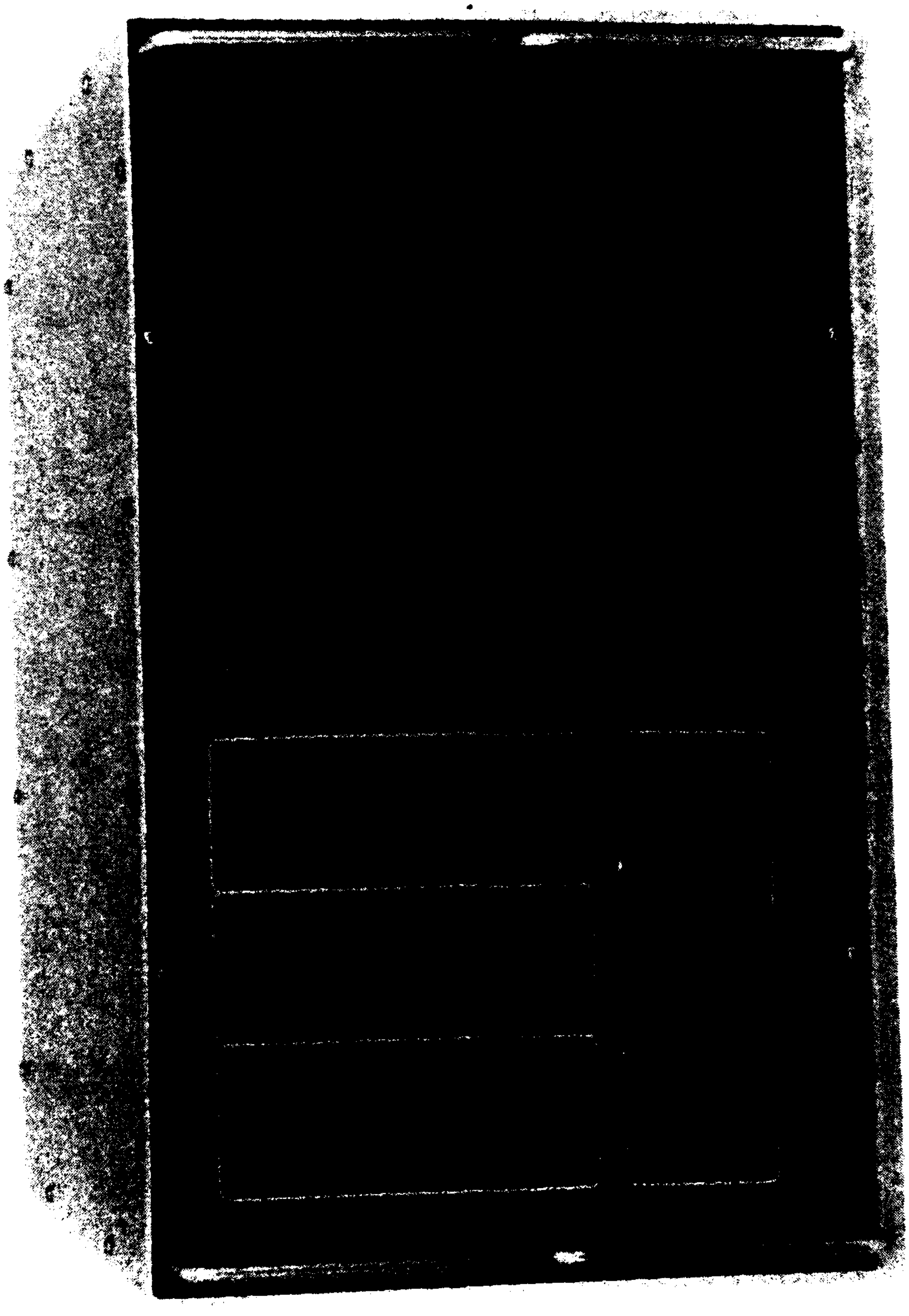


Figure 3-1. Distribution Center

Figure 3-2 shows the indicators and controls on the Distribution Unit front panel, and the restrictions on their use. Figure 3-3 shows the external connections to the Distribution Unit for Two-Port mode operation. These connections are mandatory.

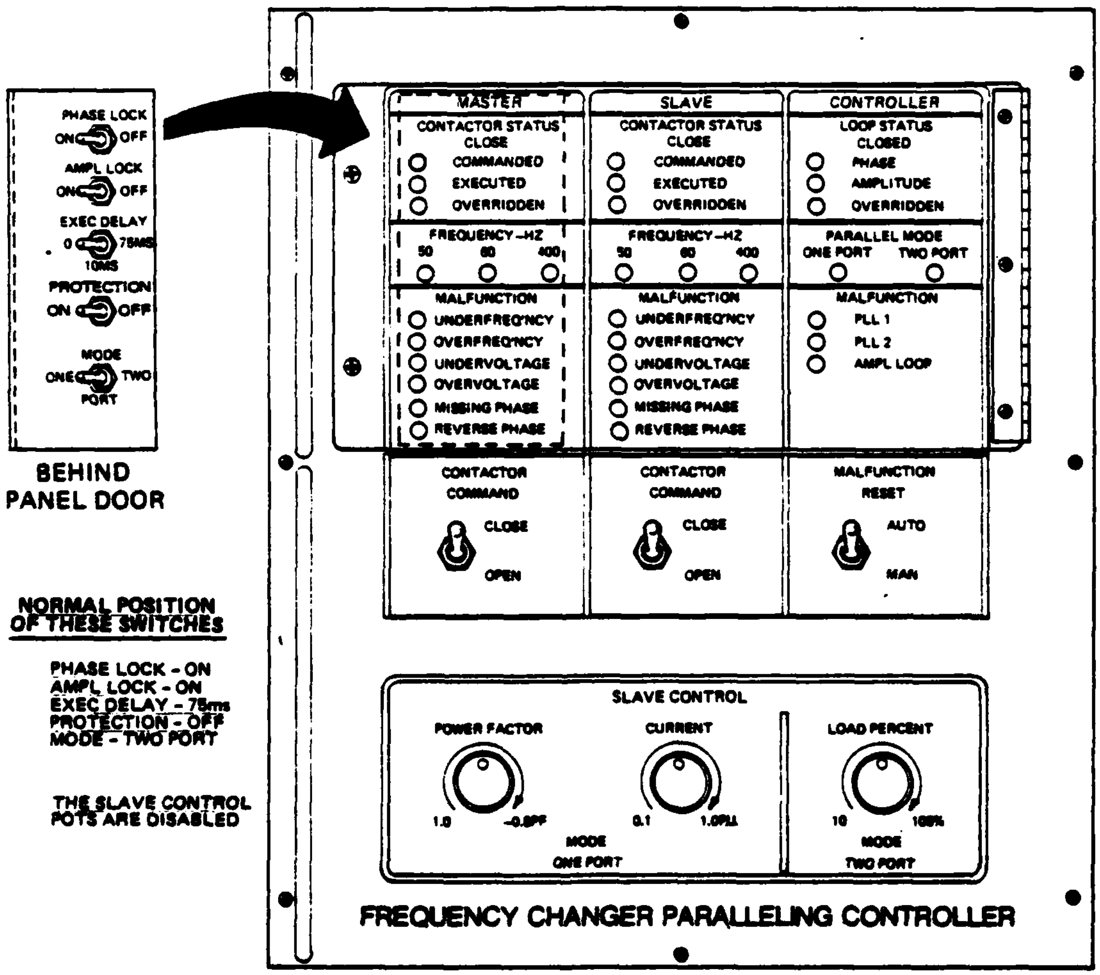


Figure 3-2. Closeup of Distribution Center Front Panel Indicators and Controls

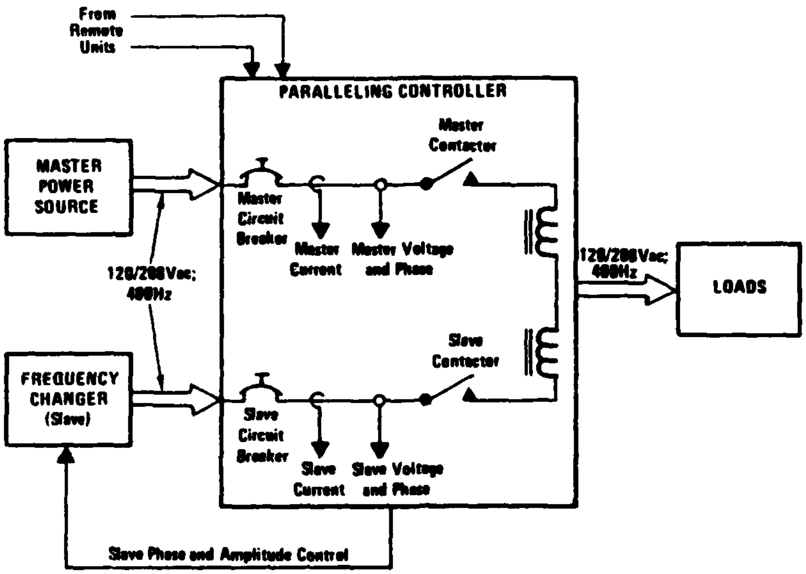


Figure 3-3. Two-Port Mode Connection

3.3 DETAILS OF IMPLEMENTATION

Two control outputs are developed in the Distribution Unit and sent over the remote control cable to the 15 kW Frequency Changer (Slave). Both control outputs are encoded into pulse trains and transformer isolated for low susceptibility to noise. Figures 3-4 through 3-7 show the circuitry which provides amplitude control and phase control.

The amplitude and phase bias signals, shown in Figure 3-4 and 3-6, are supplied by Remote Unit 2 from digital-to-analog converters. By this implementation, the Touch Screen Controller can change the amplitude (power) and phase (power factor) of the Slave Unit in a paralleling operation. Appendix M provides the electrical schematic diagrams of the Distribution Unit.

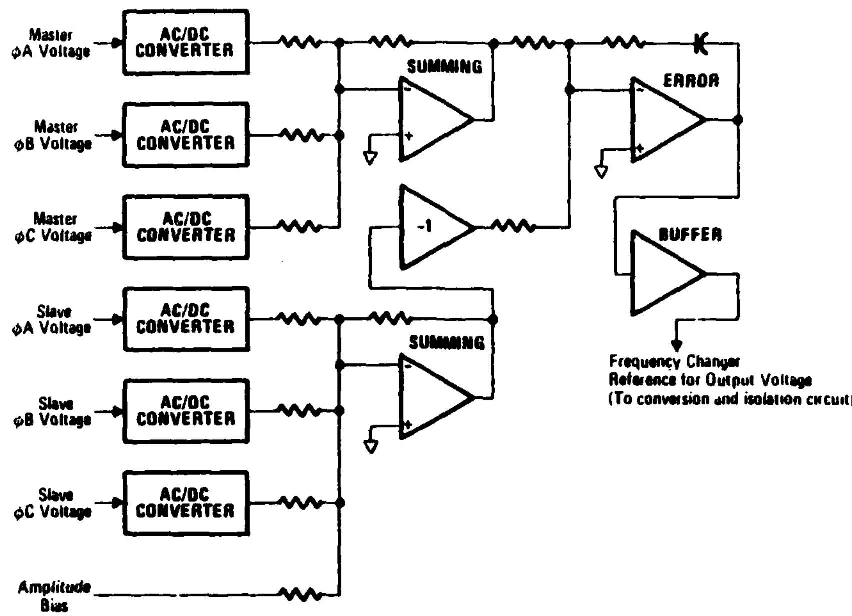


Figure 3-4. Amplitude Control Loop

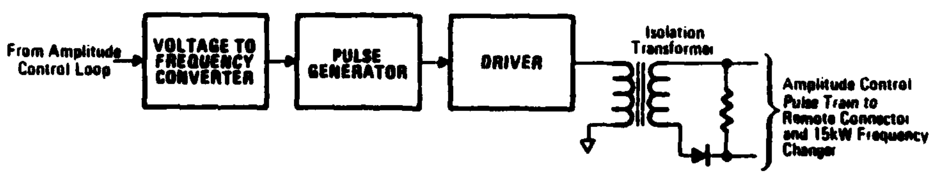


Figure 3-5. Amplitude Conversion and Isolation Circuits

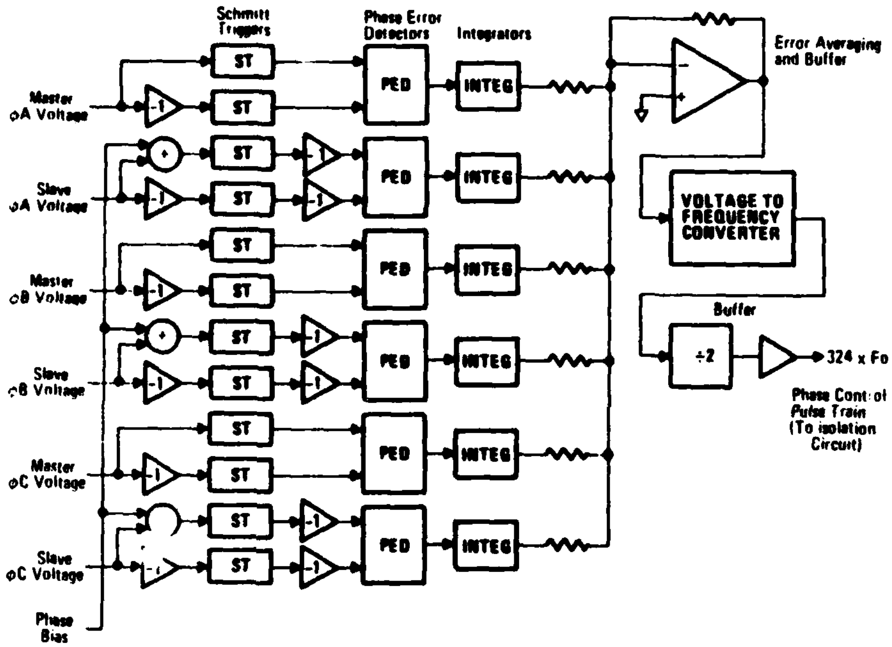
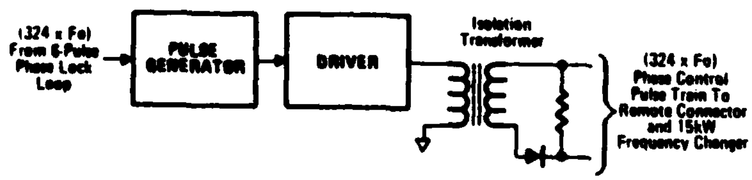


Figure 3-6. Six-Pulse Phase Lock Loop



Figuure 3-7. Phase Isolation Circuit

SECTION IV

15 kW GENERAL PURPOSE FREQUENCY CHANGER

4.1 BACKGROUND

Development of the 15 kW General Purpose Frequency Changer commenced in 1976. In the course of development Delco generated numerous reports* describing the 15 kW Frequency Changer and it's integral parts. This unit uses input power of 120/208 Vac, three phase, either 3 or 4 wire. The input frequency may be 50, 60, or 400 Hz; although at present, the fans and low level power supplies must be operated at 60 Hz only. In general, the quality of the power source should be MIL-STD-1332, utility Class 2B or better.

The 15 kW Frequency Changer (Figure 4-1) supplies at its output 120/208 Vac, three phase, either 3 or 4 wire. The output frequency may be the same or different than the input frequency, and may be 50, 60, or 400 Hz. The general quality of the output power is MIL-STD-1332, precise Class 1.

4.2 EFFORT FOR FY82

When it was orginally built, and until 1980, the 15 kW Frequency Changer had none of the remote control features necessary for paralleling its output with other power sources. In 1980, as a part of the contractual effort called the 15 kW General Purpose Frequency Changer Performance Improvement Program, these features were added.

* Inverter Section For 15 kW General Purpose Power Conditioner. Technical Proposal P77-2. Delco Electronics Division, General Motors. (Feb 1977)

15 kW General Purpose Power Conditioner - AC/DC Section. Final Report R78-38. Delco Electronics Division, General Motors. (April 1978)

15 kW General Purpose Power Conditions. Test Report R80-122. Delco Electronics Division, General Motors (September 26, 1980)

15 kW General Purpose Power Conditioner, Inverter/Converter Integration. Technical Report R80-142. Delco Electronics Division, General Motors. (October 1980)

15 kW General Purpose Frequency Changer Performance Improvement. Technical Report R81-31. Delco Electronics Division, General Motors. (March 12, 1981)

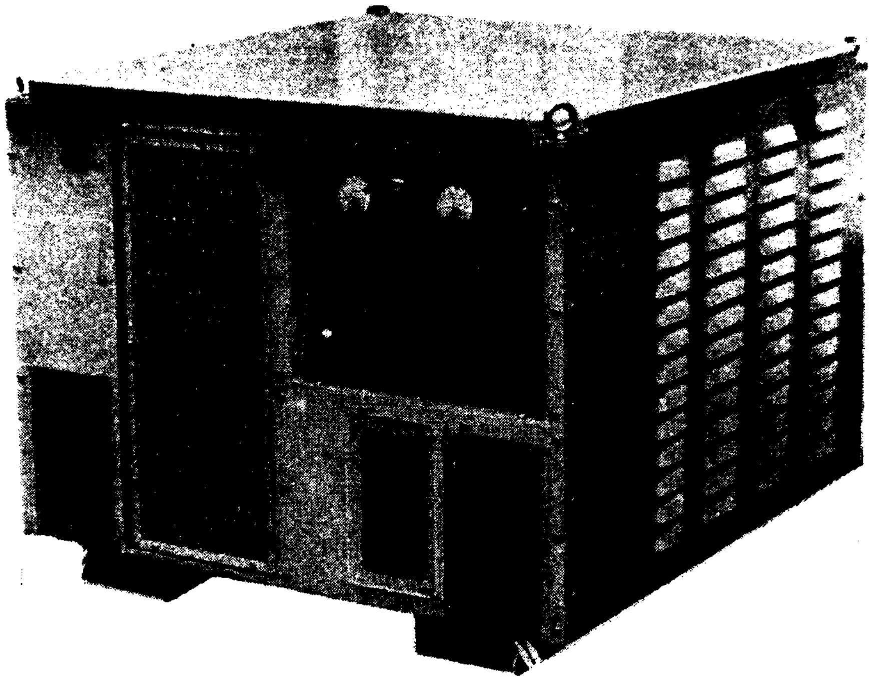


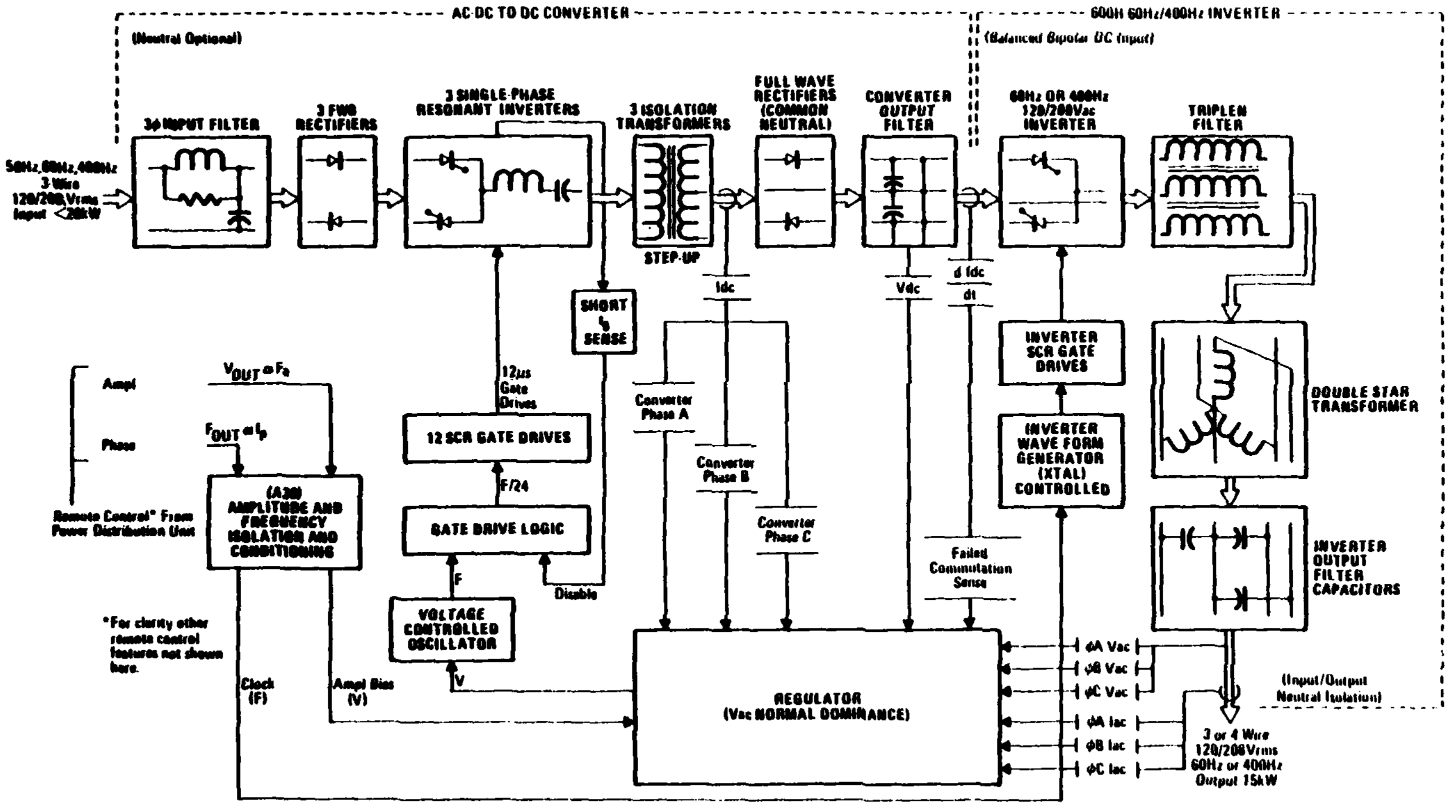
Figure 4-1. 15 kW Frequency Changer

For purposes of the MY82 IR&D Paralleling Control Project, these remote control features of the 15 kW Frequency Changer were deemed satisfactory and remained essentially unchanged.

Figure 4-2 is a block diagram of the 15 kW Frequency Changer. The remote control features necessary for paralleling and described by the block called Amplitude and Frequency Isolation and Conditioning were added in 1980.

4.3 DETAILS OF IMPLEMENTATION

For purposes of paralleling, two characteristics of the 15 kW Frequency Changer's output must be controlled: output amplitude and instantaneous output frequency. The primary function of the circuit card A30 added in 1980 is to permit remote (external) control of these characteristics or parameters. Figure 4-3 is a simplified block diagram of the circuitry for implementing output amplitude control in the external (paralleling) mode. The input is a contin ous pulse train with a nominal frequency of 50 kHz. This is isolated from the chassis by a small transformer.



NOTES ON REGULATOR:

A. For normal load conditions, the Vac loops are dominant.
B. For slight overloads, Iac, Idc, or Idc x Vac loops are dominant.
C. For severe overloads and short circuits, Iac or Idc loops are dominant.
D. For severe transients, the failed commutation loop is dominant so as to facilitate inverter commutation.
E. For independent converter operation, and for overvoltage protection, if inverter failure occurs, the Vdc loop is dominant.
F. The Idc x Vac (or power) loop may not be used.

Figure 4-2. Frequency Changer Block Diagram

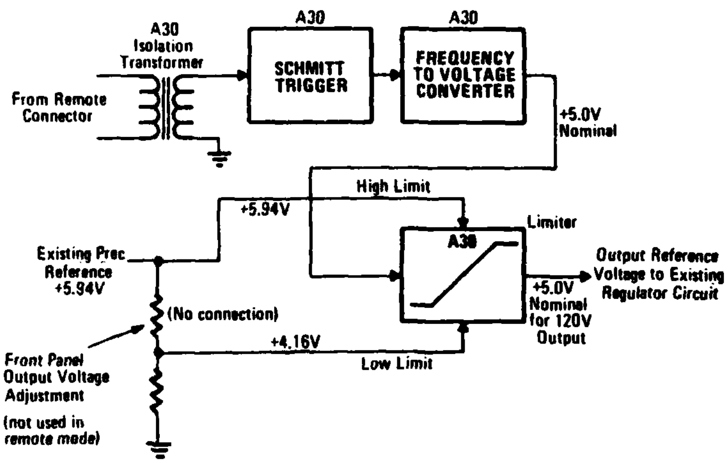


Figure 4-3. External Amplitude Control

The pulse quality in Figure 4-3 is improved with a Schmitt trigger, which produces a clean frequency. For control purposes, this frequency is converted to voltage. This voltage is applied to a limiter which constrains it to a range corresponding to the nominal output voltage adjustment range of the set.

Three important features of the set's externally controlled output voltage implementation are:

1. Pulse frequency modulation PFM with full transformer isolation is used for extremely high noise immunity.

2. A limiting function is applied to the external control so that even invalid external control cannot cause set output to be out of range.

3. The time response of the external amplitude control circuit (including the frequency to voltage converter) is much faster than that of the internal amplitude control loop, and therefore has a negligible effect on control performance.

Figure 4-4 is a block diagram of the implementation of the output frequency (and phase) control in the external (paralleling) mode. The input is a continuous pulse train with a nominal frequency as follows:

- 50 Hz operation - 16,200 Hz
- 60 Hz operation - 19,440 Hz
- 400 Hz operation - 139,600 Hz

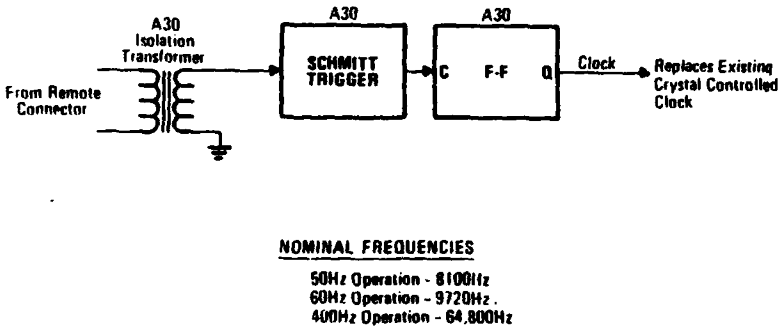


Figure 4-4. External Phase Control

This input pulse train is isolated from the chassis by a small transformer. Pulse quality is improved with a Schmitt trigger. The Schmitt trigger is followed with a toggled flip-flop to give a clock with one half the frequency listed above and a 50 percent duty cycle. For the purpose of frequency (and phase) control, the externally supplied clock is used to replace the internal crystal derived clock.

Appendix N contains a complete set of schematic diagrams of the electrical and electronic circuits of the 15 kW Frequency Changer. This set has minor revisions over previously published sets.

SECTION V

SYSTEM INTEGRATION AND TEST

5.1 THE LABORATORY SETUP

For demonstration purposes a small, yet typical, power distribution system was set up (Figure 5-1) in Delco's Solid State Power Labortory. The Touch Screen CRT Controller serves as the operator interface. By a total of 4 fiber optic "wires" it enables control of the Distribution Unit and permits monitoring of the system status through the Distribution Unit. The two Remote Units are an expedient for quick and easy hardware development. Since these two units serve as communications intefaces for the Distribution Unit, they would otherwise be incorporated in the Distribution Unit.

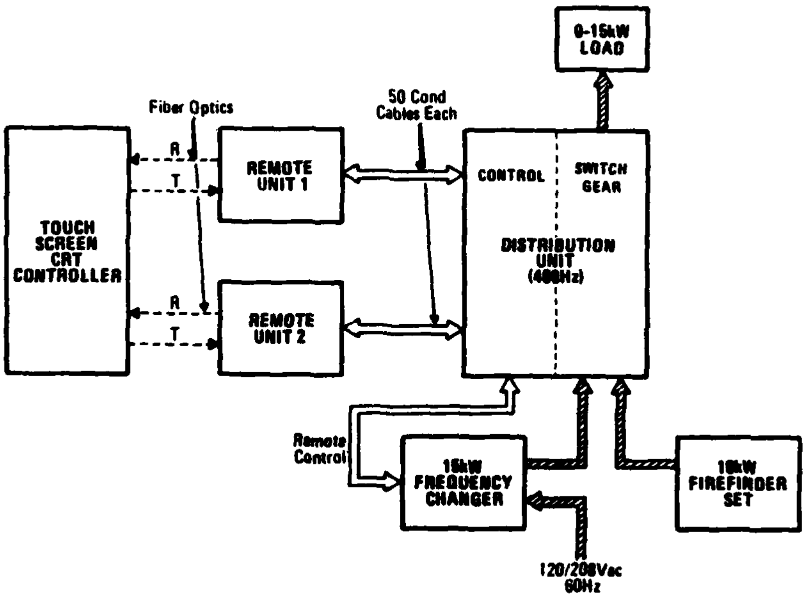


Figure 5-1. Integrated Power Distribution System Block Diagram

The 15 kW Frequency Changer is remotely controlled through the Distribution Unit. For purposes of this demonstration the frequency changer is the only source capable of remote control and must, therefore, be used as the Slave Unit. The 10 kW Firefinder generator set was chosen as the Master Unit. The demonstration was conducted at 400 Hz only.

Figure 5-2 shows the laboratory setup of the power distribution system. From left to right are the Touch Screen Controller, the Distribution Unit, the 15 kW Frequency Changer, and the 10 kW Firefinder PCU. The 10 kW Firefinder PCU is mounted on top of a cooling fixture. The turbine is located in a test cell in another building.

Figure 5-2. Laboratory Setup of Power Distribution System

The Remote Units are located beneath the Distribution Unit and are concealed by the cloth. The reason for this concealment is, as explained in more detail elsewhere, the Remote Units would be included as an integral part of the Distribution Unit.

5.2 DEMONSTRATION AND TESTING

5.2.1 NETWORK DEMONSTRATION

The equipment used for this demonstration (Figures 5-1 and 5-2) was extensively tested. Remote switching, monitoring, and control of paralleling was successfully tested. Especially significant was the performance of "transient free" transfer. Recorded transients were in all cases within the transient response signatures of the 15 kW Frequency Changer and the 10 kW Firefinder Set.

Figure 5-3, 5-4, and 5-5 show three typical touch screen displays recorded during a paralleling demonstration. Note that Unit 1, the 10 kW Firefinder Set, is supplying 2.8 kW to the load bus.

Figure 5-3. Summary Display - Touch Screen CRT

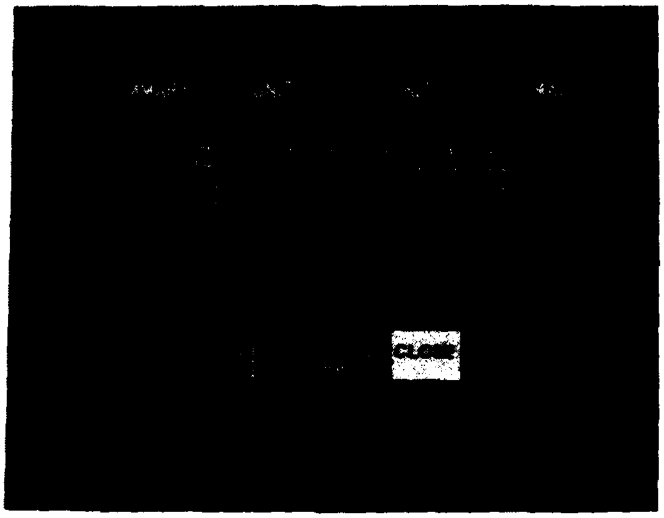


Figure 5-4. Unit 1 Display - Touch Screen CRT

Figure 5-5. Unit 2 Display - Touch Screen CRT

Concurrently, Unit 2, the 15 kW Frequency Changer is supplying 4.1 kW to the load bus. More data are presented in the following appendixes.

- Appendix B - Source Power Transfer Testing
- Appendix C - 15 kW Frequency Changer Load Change Induced Transient Signature
- Appendix D - Effect of Bus Frequency Changes During Parallel Operation
- Appendix E - Phase Lock Capture Behavior
- Appendix F - Effect of Frequency Changes on Phase Lock

5.2.2 INPUT CURRENT HARMONIC REDUCTION

This section deals with the first of two major unscheduled efforts involving a major part of the Network Demonstration of the 15 kW Frequency Changer. Input voltages and currents from the 60 Hz, 120/208 Vac, plant distribution bus were recorded and analyzed for distortion components. This was done both before and after a dramatic improvement was made to the input filter. Data from these tests are provided in the following appendixes:

- Appendix G - 15 kW Frequency Changer Input Current Waveform Testing With Original Input Filler
- Appendix H - 15 kW Frequency Changer Input Current Waveform Testing With Augmented Input Filter

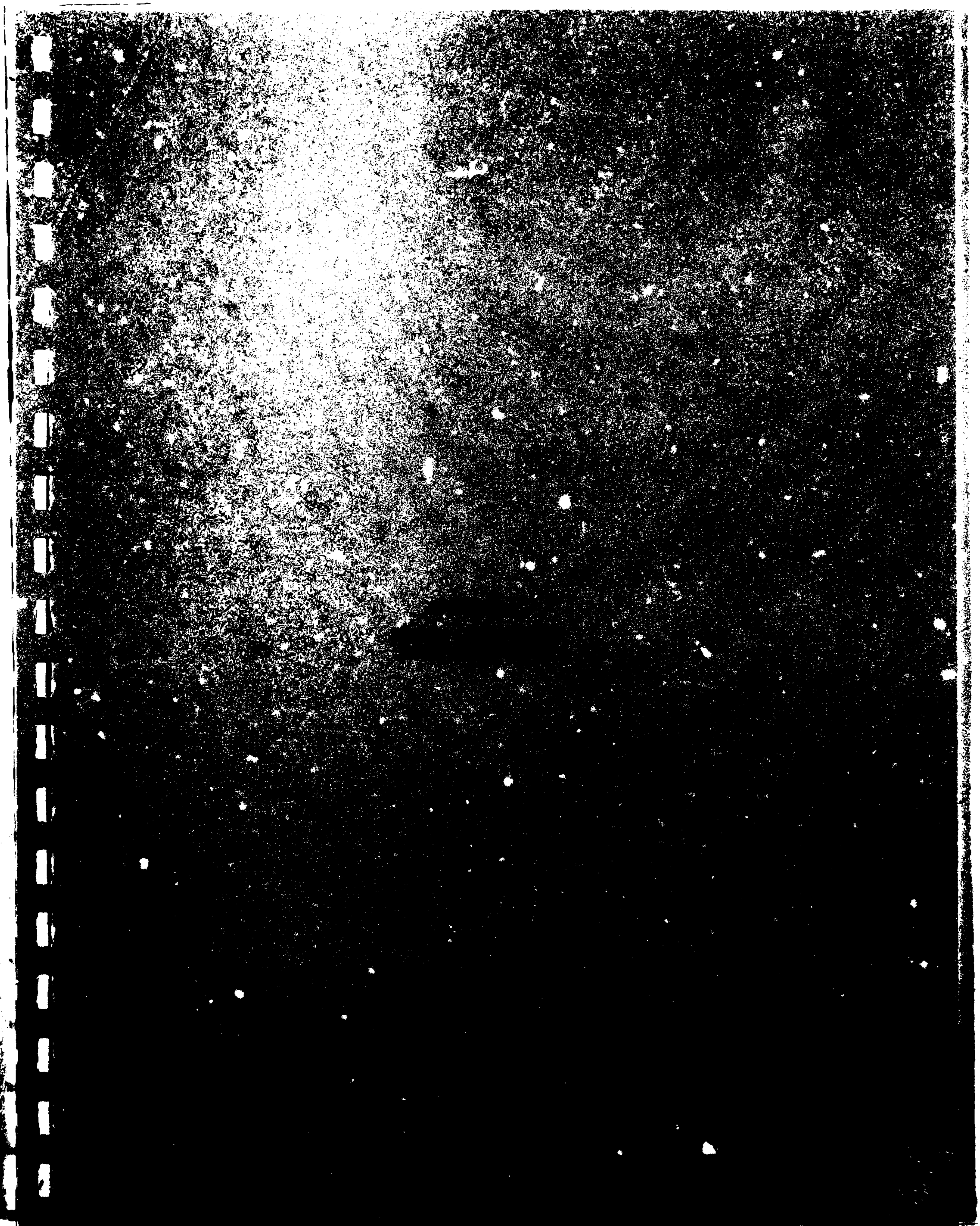
5.2.3 EFFECTS OF NONLINEAR LOADS ON THE 28-SCR DELCO INVERTER

This section deals with the second of two major unscheduled efforts involving the Delco inverter. Because of Navy's interest in how well the 28-SCR Delco inverter would perform when supplying typical power supply type (highly non-linear) loads, the 10 kW Firefinder Set was operated with several such loads. Because suitable power supplies were not on hand, their input characteristics were approximated with nonlinear test load configurations.

With some load configurations, a comparison was made between the 10 kW Firefinder Set and a typical 12.5 kVA motor-generator set. Results show that the 28-SCR Delco inverter (10 kW Firefinder PCU) gives far better bus waveform when operating into a nonlinear load than does a similarly sized motor-generator set. Data from these tests are provided in the following appendixes:

- Appendix I - Inverter Output Waveform Degradation With Nonlinear Loading

- Appendix J - Testing With Single Phase Nonlinear Loading



E80-03 SOLID STATE POWER

INTRODUCTION

The ultimate goal of this project is the definition and demonstration of modern tactical power distribution methods using modular solid state building blocks. The emphasis is on an integrated systems approach that includes power conditioners, distribution centers and controllers for network status reporting and power control.

Status

The status of Delco's overall solid state power program through MY81 is as follows.

- Power Distribution and Control: Evaluated several concepts, solicited tri-service feedback, demonstrated power source sensing and paralleling (under contract DAAK70-77-C-0157), and initiated microprocessor based network controller design which incorporates "touch screen" CRT display plus fiber optic data communication links.
- Power Conditioning
  - Inverters: Completed initial production of the MEP-D423A generator set inverter (Contract DAAK 70-79-C-001) which resulted from previous IR&D activity.
  - Frequency Changers: Completed and demonstrated 15 kW, 60/400 Hz prototype Army unit (Contract DAAK 70-77-C-0157).
  - Converters: Delco in-house efforts reduced earlier 4-SCR converter approach (Contract DAAK 70-77-C0035) to use of 2-SCR power modules; developed universal fixture and controls for high frequency, high power converter studies.

BACKGROUND

Delco is currently developing and producing high power inverters and frequency changers for Army tactical use. These development activities have been aimed at reducing military dependence on the use of engine generation sets in lieu of local utility power. In recent years, changes have occurred in the perception of combat environment needs which make it apparent that power conditioner

development cannot focus solely upon the specific performance requirements of individual power conditioning units, but must also consider the larger system aspects of diagnostics, interface, control, and performance within the total tactical power distribution network. These concerns are addressed in our long term IR&D Plan which takes a top-down systems approach to defining total tactical needs and developing a family of modular system building blocks to satisfy those needs. To achieve the overall objective, Delco is taking advantage of recent Government/Industry efforts by selectively adapting emerging technology to those earlier achievements which show promise of satisfying the stated critical need.

In the area of power distribution, the Marine Corps has developed and tested (1976-1979) prototype power panels and associated cables which provide a very good baseline for meeting the needs of the standard distribution system. These rugged prototypes are definitively specified by MIL-P-29183 (Navy) for the panel boards and MIL-C-29184 (Navy) for the cable assemblies. The system (referred to as MEPDIS) provides local circuit breaker fault protection, but has no provision for centralized control/management and does not address paralleling or control of diverse power sources. Recent technology advances allow expansion of the MEPDIS capability to include these essential control features.

In the area of power conditioners, Government agencies and industry have been applying solid state power device technology advances to achieve replacements for engine generators. 1.5 kW to 15 kW prototype systems have been developed which meet Army mobile electric power requirements. Navy shipboard prototype 60 to 400 Hz frequency changers have been demonstrated to 250 kW levels. Delco/Army have successfully provided full scale engineering development and production of a 10 kW conditioner for the Army's Firefinder TPQ-36 radar.

PROBLEM

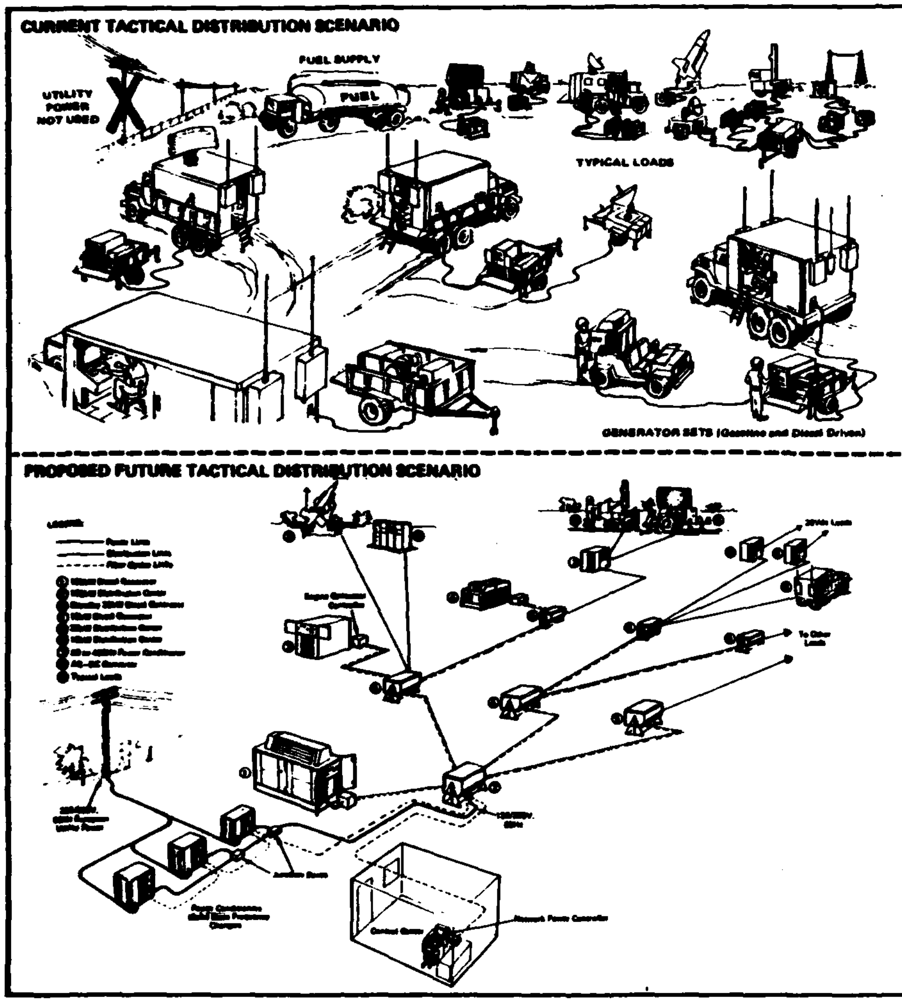
The present tactical power distribution methodology requires that a tactical generator set, specific to the load system, be co-located with each load and be compatible in voltage, frequency and quality of power. As a consequence,

logistic support of fuel supply and maintenance for the power source must be provided to the user site. This situation results from a lack of power conditioning equipment which can convert available power to user requirements, and from a lack of general purpose distribution systems which can supply power to a number of users from a single central source. In addition to its impact on logistics, correction of the present deficiency will reduce noise and extend the life of small tactical generators by reducing reliance on them to those occasions when no other source is available, or as back-up in the event of a power conditioner failing. It should also eliminate the existing problem of not being able to operate U.S. forces equipment with equipment of other nations due to differences in voltage and frequency.

Figure 1 contrasts a current tactical distribution scenario with a future distribution scenario representing Delco's approach to solving the problem. This concept evolved from close interchange between our power systems engineers and tri-service users. This integrated system approach draws upon current and evolving technology in the areas of solid state power, microprocessor/computers, optical link data exchange and CRT display. The resultant distribution network provides fuel or energy management through centralized power source and load control, plus rapid deployment/high mobility via local center disconnect and control features.

The upper table in Figure 1 indicates, for various applications, the potential for reducing both the equipment complement and the operating costs accruing from the use of standardized power distribution networks and power conditioners. The existing mode tactical field data (applications 1 through 6) were taken from a BDM Corporation study "Evaluation of Tactical Electric Power Distribution Systems" submitted to the Army Mobility Equipment Research and Development Command (MERADCOM). Fixed site data (applications 7 and 8) were taken from USAF Missile Weapon System data available at Delco and information provided through the DOD Project Manager for Mobile Electric Power (PMMEP).

The lower table in Figure 1 illustrates the potential for extending operating life of small tactical generators since a very high percentage of these units are not required during standard network operation. This greatly enhances the availability of these engine generators for stand-alone operation when they



IN MOST APPLICATIONS BOTH COST AND EQUIPMENT COMPLEMENT WILL BE SIGNIFICANTLY REDUCED

POWER DISTRIBUTION APPLICATION EXAMPLES	EXISTING MODE (Diesel/gas, 50% duty cycle)					PROPOSED DISTRIBUTION MODE (European utility, 50% duty cycle)							
	Power Needs (kW)	Number of Engine Generators			Fuel Cost/Month at $1.20/gallon	Power Cost at $.07/kW-hour	Distribution Centers			Network Controllers	AC/DC Converters	Frequency Changers	Standby Engine Generators
		AC	DC	Stby			10kW	30kW	100kW				
Infantry Battalion Headquarters	52	5	12	8	7,580	1,300	6	2	–	1	5	1 (60kW)	3
Artillery Battalion Headquarters	58	6	8	4	8,290	1,460	6	2	–	1	5	1 (60kW) 1 (10kW)	3
Forward Communications Company	74	11	0	4	7,930	1,860	8	2	1	1	0	1 (100kW)	3
Heavy Maintenance Company	47	11	3	4	8,640	1,175	6	2	–	1	2	1 (60kW)	3
Medical Company	36	3	1	2	4,680	900	4	1	–	1	1	1 (30kW) 1 (10kW)	2
Headquarters Support Command	200	2	0	0	10,440	5,000	6	6	2	1	0	2 (100kW)	1
Fleet or Base Hospital	760	1	0	1	40,834	18,760	40	16	7	3	1	3 (250kW)	1
Missile Silo (United States Based)	800	–	–	2	NA	12,500	30	12	6	3	6	—	2

SUMMARY OF SAVINGS USING PROPOSED DISTRIBUTION METHODS

APPLICATIONS	ENGINE-GENERATOR SETS REDUCED BY:	POWER COSTS PER MONTH REDUCED BY:
Infantry Battalion Headquarters	19 sets not used (86%)	$6,280 per month saved (83%)
Artillery Battalion Headquarters	14 sets not used (82%)	$6,830 per month saved (82%)
Forward Communications Company	12 sets not used (80%)	$6,070 per month saved (77%)
Heavy Maintenance Company	15 sets not used (83%)	$7,465 per month saved (86%)
Medical Company	4 sets not used (66%)	$3,780 per month saved (81%)
Headquarters Support Command	1 set not used (50%)	$5,440 per month saved (52%)
Fleet or Base Hospital	NO REDUCTION	$22,074 per month saved (54%)
U.S. Based Missile Silo	NO REDUCTION	NOT APPLICABLE

Figure 1. Distribution Scenarios — Solid State Conversion and Distribution Reduces Cost and Dependence on Engine Generator Sets

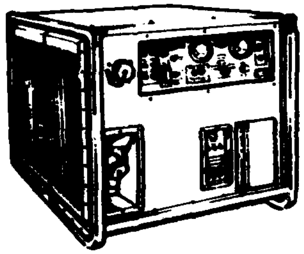
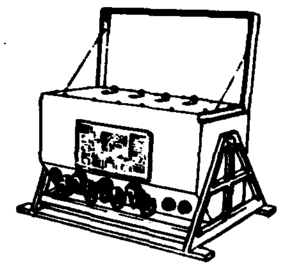
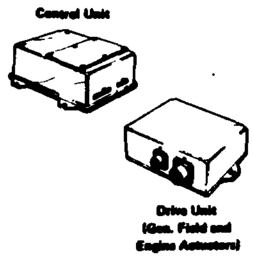
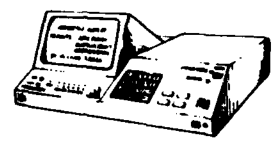
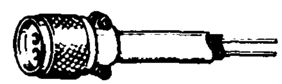
POWER CONDITIONERS	DISTRIBUTION CENTERS	ENGINE GENERATOR CONTROLLERS	NETWORK CONTROLLERS	FIBER OPTIC LINKS
				
KEY FEATURES • Utility (U.S. and European) or dc voltage inputs • Input Line Current, THD < 3% • Microprocessor/optical link interface • Diagnostic and fault monitor • Lightweight, rugged units.	**KEY FEATURES** • Microprocessor/optical link interface • Remote or local control of centers • Rapid couple/decouple to network • Standard cables and connectors • Dual power frequency operation (60 or 400 hertz).	**KEY FEATURES** • Microprocessor-based control • Remote or local control • Automatic paralleling • Diagnostic and fault monitor • Optical link data exchange • Rugged control unit.	**KEY FEATURES** • Microprocessor based control • "Touch screen" interface with sources and load centers • Diagnostics and fault monitor • Optical link data exchange • Compact, rugged unit.	**KEY FEATURES** • Low loss, wide bandwidth • Secure data transmission • No radiation/low susceptibility • Rugged and lightweight.
DEVELOPMENT STATUS • Delco 10kW Inverter in field use Army "Firefinder" (DAAK70-79-C-0001) • Delco/Army 30kW Converter (DAAK70-77-C-0035) • Delco/Army 15kW Frequency Changer (DAAK70-77-C-0157) **ADDITIONAL DEVELOPMENT REQUIRED** • Microprocessor/optical link interface • Diagnostics/fault monitor • Adapt for field use.	**DEVELOPMENT STATUS** • USMC built prototypes (1975–1979) • 15/30/100kW centers manual control • Rugged, field-tested cables and centers. **ADDITIONAL DEVELOPMENT REQUIRED** • Microprocessor/optical link interface • Remote and local control • Dual power frequency operation (60 or 400 hertz) • Adapt for field use.	**DEVELOPMENT STATUS** • Navy basic development of 30kW Engine Generator Controller (1975-1981) • Delco development of Fuel Injection and Engine Controller (1980-1981). **ADDITIONAL DEVELOPMENT REQUIRED** • Incorporate paralleling controls • Adapt microprocessor-based controls • Network interfaces • Adapt for field use.	**DEVELOPMENT STATUS** • Conceptual design and layout (Delco IR&D, 1980 and 1981) • Delco demonstration of "touch screen" control in autos (1980 and 1981). **ADDITIONAL DEVELOPMENT REQUIRED** • Controller software • Integrate with optical link • Integration and demonstration with network elements. • Adapt for field use.	**DEVELOPMENT STATUS** • Standard fiber cables available • Optical drivers/sensors available. **ADDITIONAL DEVELOPMENT REQUIRED** • Develop control interfaces • Network interface/test • Adapt to field use.

Figure 2. Power Network Building Blocks -- Required for a Systems Approach to Satisfying Total Tactical Power Needs

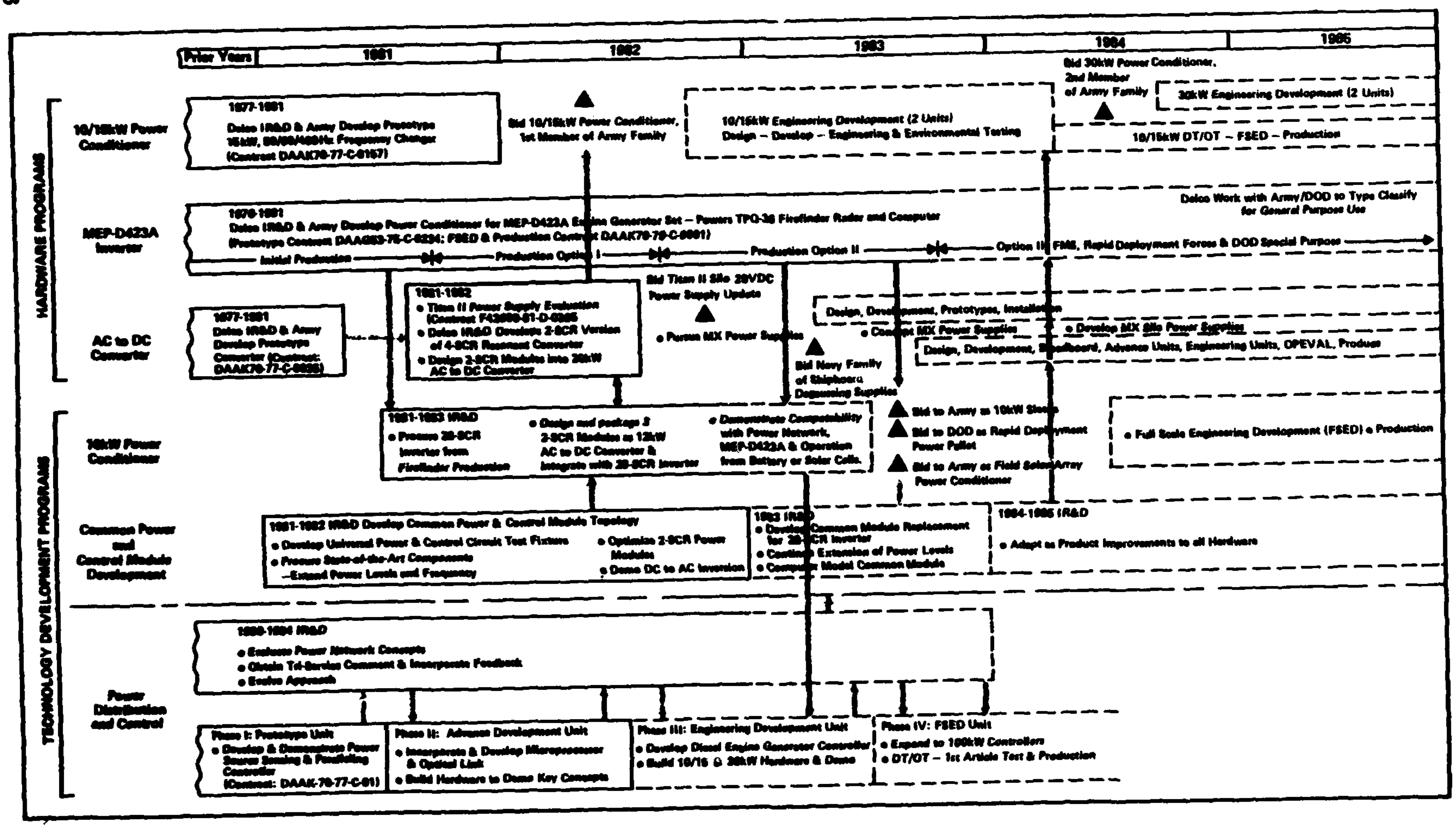


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Figure 3. Overall Program Plan

are needed for combat or training exercises (less than 20% of time). The power cost reduction data was based upon 1981 costs of fuel and electricity in Southern Germany. Assuming continuation of present trends, these figures will reflect even more favorably upon use of local utilities to power standard distribution networks in the future.

OBJECTIVE

Overall Objective

The overall objective is to achieve circuit commonality among various types of power conditioners and to develop a standard power distribution system that can interconnect, monitor and control tactical power generators and loads. The required power distribution network design must provide efficient direction of power from a primary source to various loads, and provide capability for quickly adding or deleting alternate power sources or loads to the network. Delco's modern distribution network scheme is capable of meeting these needs through development and integration of the necessary distribution network building blocks. Figure 2 shows key features and development status of each network element. Additional development required is primarily concerned with adapting the demonstrated technology to a specific application and carrying it forward to tactical field use. Integration of microprocessor and optical link technology into any system requires detailed knowledge of overall requirements before proceeding with the extensive software development to effectively adapt the proven hardware items. Therefore, an important objective is to obtain tri-service user agreement and system specification for a DOD standard network.

MY82 Objectives

Objectives for MY82 are to:

1. Demonstrate the feasibility of the Delco distribution network concept as the basis for obtaining Government funding for a follow-on Engineering Development Phase. The feasibility demonstration effort was initiated in MY81; the associated hardware/ software development will be completed in MY82. In August 1981 through a Government Loan Agreement, the Army provided Delco with 15 kW power conditioner and power controller hardware for use in the MY82 demonstration.

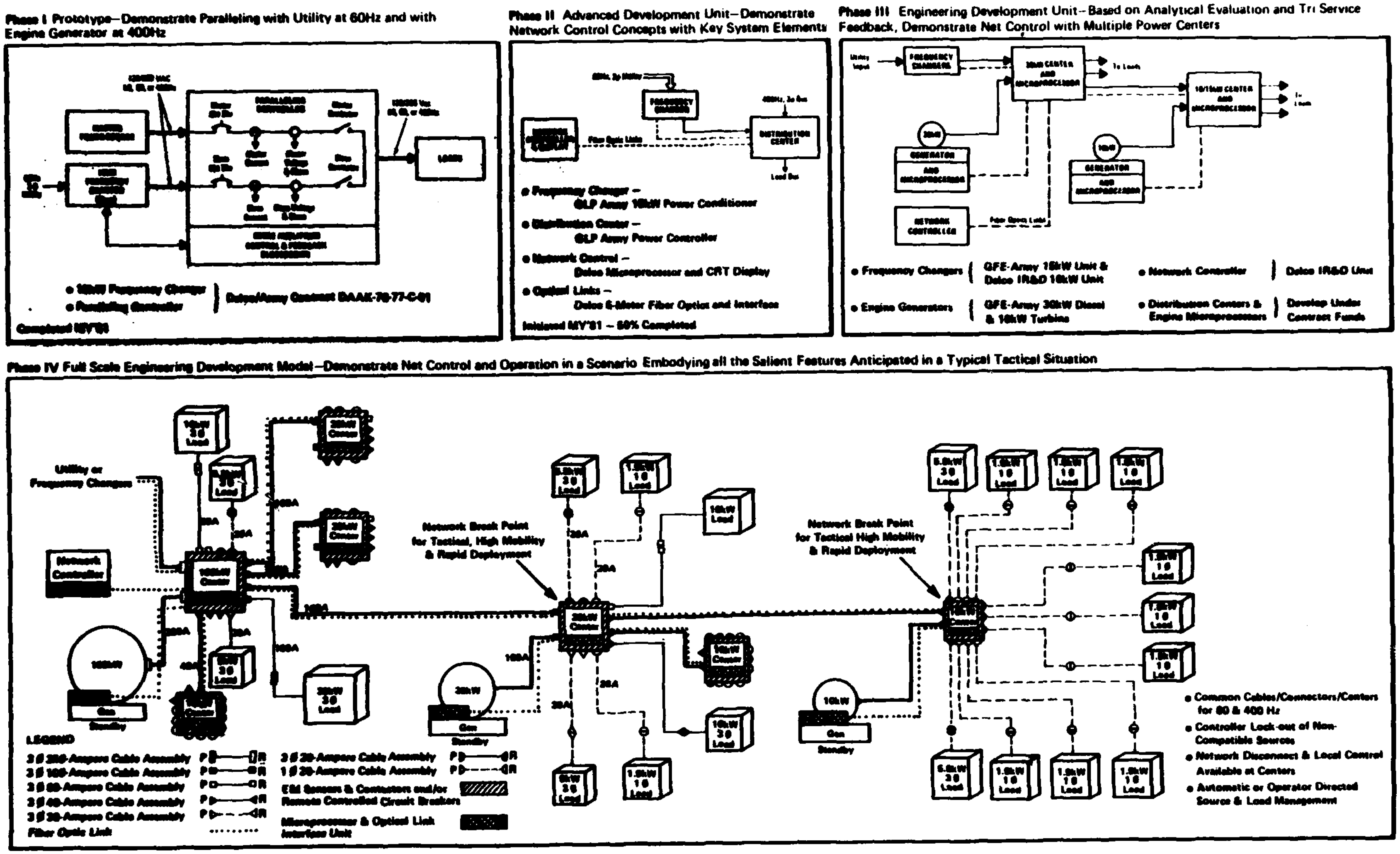

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Figure 4. Power Distribution Network Demonstation Evolution Plan

2. As part of the continuing effort, started in 1981, develop common power and control modules and demonstrate a six kilowatt, 2-SCR common module which operates at frequencies up to 16 kHz. The common control circuit under development will allow the new module to function as part of an ac-to-dc converter or dc-to-ac precision sinewave inverter and be applicable to various types of power conditioners or power levels.
3. Demonstrate commonality features by adapting the new common module to a 10 kW frequency changer. The new unit will integrate an Army 28-SCR Firefinder production inverter with three 2-SCR common module converters.

Our detailed approach for achieving these objectives is described in the following section.

APPROACH

Delco's overall five year development plan for solid state power is shown in Figure 3. The upper section shows an overview of Government hardware programs in process or planned, and how Delco IR&D effort has focused on these production efforts. The lower sections shows how current Delco technology development is directed toward the Objectives stated. The overall thrust is toward yearly technology advances, coupled into hardware programs, both to support competitive bidding activity and to provide product improvement in power systems production programs.

Power Distribution

To demonstrate power distribution network control, Delco will utilize the advanced, proven technology developed for GM automotive use, plus procedures and design techniques developed to provide environmental protection, high reliability, ruggedness, and ease of use. Every GM domestic passenger car since 1981 has at least one sophisticated microcomputer for engine control and as many as four more for controlling operator displays and comfort, convenience, and entertainment functions. Current microcomputer production rates of over 20,000 units per day make Delco the world's largest manufacturer of small computers.

The automobile environment is comparable to the tactical field environment. EMI and power bus transient requirements exceed MIL-STD-461, and exposure to temperature cycles and extremes, vibration and shock, fuels, coolants, solvents, and water are normal occurrences. Control and display operator interfaces have to be rugged, tolerant of abuse, and (most importantly) easy to use and understand by untrained operators. Extensive built-in-test and continuously running diagnostics are essential for the service of these sophisticated microcomputers by relatively untrained service technicians. Major emerging automotive technologies to be used to demonstrate the concept of power network control include:

- Microcomputers - Eight-bit microprocessors based on the Motorola 6800 family, and 16-bit microprocessors based on the Intel 8086 family with attendant memory, A/D, and I/O chips; system configurations employing distributed processing and co-processing serial communications techniques.

- Fiber Optics - Communication links to route multiplexed serial data between microcomputers and systems; high data rate, EMI-proof, rugged, low cost.

- "Touch Screen CRT" - Simple, compact means to eliminate all mechanical switches and controls and dedicated individual displays; all displays and control functions combined in a ruggedized small screen CRT with a touch sensitive face; totally flexible display format of alphanumerics and graphics; self-prompting, easy to understand presentation formats.

- "Hardened Design Techniques" - Specific circuit and system designs address EMI/RFI, fail-safe, fail-soft with backup, hardware and software self-test, and constantly running system diagnostics.

Figure 4 illustrates the phased approach being taken to achieve the stated Objective, to provide a standard network required by DOD, as described in the problem statement.

Phase I (1980-1981). The MY80 IR&D results led to an added scope item to a Delco/Army 15 kW Frequency Changer Development Contract to demonstrate the capability of paralleling the unit with 60 Hz, 3-phase utility or 400 Hz, 3-phase engine generators (60 kW, EMU-30). This effort proved the sensing and control circuit concepts and resulted in a Government loan of developmental items for Delco's IR&D distribution network Phase II effort.

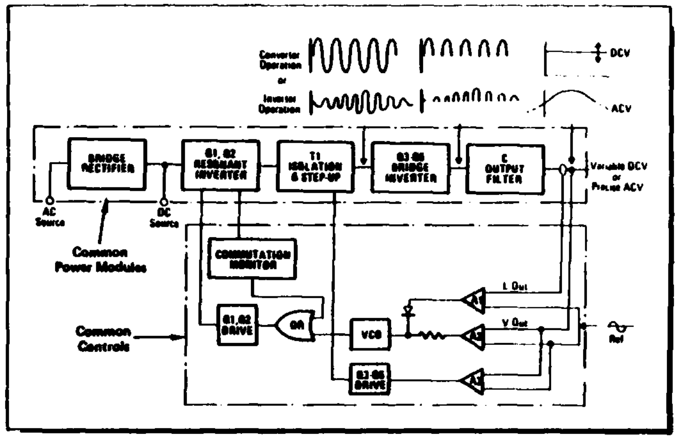
Phase II (1981-1982). Advanced Development Unit hardware design and fabrication began late in MY81 after securing tri-service user feedback and the Government loaned property (GLP) agreement. Based on government user review comments, the network functions were expanded to include remote control of load circuit breakers (or contactors) and control of engine generators. The updated concept incorporates microcomputers in the main controller, the distribution centers, and onboard each controlled power source. These elements are controlled via interconnecting fiber optic data links. This year's approach is to continue fabrication of Phase II hardware: the network controller (CRT display and microcomputer), the microcomputers to control the GLP, and the optical link interfaces. Software development will continue and culminate in a feasibility demonstration of the network control concepts.

Phase III (1982-1983). Engineering Development Unit hardware planning anticipates that Government contract funds will be obtained to fabricate and demonstrate deliverable distribution network items. The main technology approach during Phase III requires adaptation of microprocessor/computer control to the expanded power network. This effort would be an outgrowth of work at NAEC (Lakehurst, NJ) which demonstrated the application of microprocessor based control to a DoD standard engine generator to provide MIL-STD-704C level power. The achievements of the Lakehurst NJ group will be extended to include precise speed control of engine generators so that automatic paralleling and power transfer may be demonstrated with these sources. The Phase III effort will demonstrate network control of multiple power sources and distribution centers.

Phase IV (1983-1984). Full Scale Engineering Development (FSED) could closely follow a successful Phase III effort. The approach Delco proposes makes use of

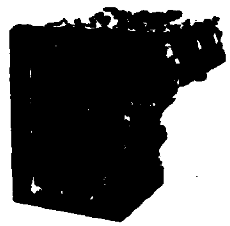
THE 10kW FREQUENCY CHANGER PROTOTYPE COMBINED BOTH CONVERTER AND INVERTER FUNCTIONS AND PROVIDES THE TECHNOLOGY BASE FOR OUR NEXT MAJOR IR & D THRUST...

...A COMMON TOPOLOGY FOR ALL CONVERTER/INVERTER POWER CONDITIONER DESIGNS...

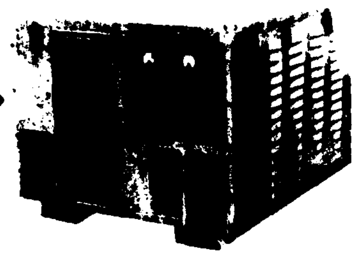


TECHNOLOGY TRANSFER

Delco IR&D and Army developed prototype 12-SCR Converter (Contract DAAK70-77-C-0028).
Input – 120/208V, 50/60Hz
Output – 0 to 300Vdc, 20kW at 300Vdc
Line Current Harmonics (THD) – < 3 percent
Volume – 3 cubic feet
Weight – 175 pounds



Delco IR&D and Army developed MEP-D423A 28-SCR inverter prototypes (Contract DAAG53-76-0234) and production (Contract DAAK70-78-C-0001).
Input – 120V, 6φ, 1,600Hz, turbine engine generator
Output – 120/208V, 400Hz
Volume – 3 cubic feet
Weight – 160 pounds



Delco IR&D and Army developed prototype 15kW, 50/60/400Hz Frequency Changer (Contract DAAK-70-77-C-01) that embodied both inverter and converter technology.

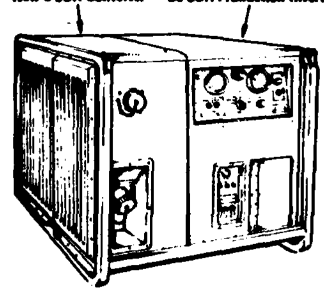
10/15kW POWER CONDITIONER COMPETITIVE DESIGNS

KEY PARAMETERS	Army Specifications	Delco Prototype	Westinghouse Concept	Varo Concept	Delco Future Concept
Weight	531 lbs	616 lbs	1,380 lbs	1,380 lbs	472 lbs
Volume	16 ft^3	12 ft^3	27 ft^3	28 ft^3	11 ft^3
Output Frequency	50/60/400Hz	50/60/400Hz	400Hz only	400Hz only	50/60/400Hz
Line Current Harmonics (THD)	<5%	<3%	<3%	<3%	<3%
Efficiency	>80%	>79%	>81%	>83%	>82%
MTBF (Calculated)	1,500h	3,013h	5,010h	3,500h	5,000h
Number of Power Switches	--	40 SCR's	60 SCR's	56 SCR's	24 SCR's

...WHICH WILL PROVIDE THE FIRST STEP TOWARDS ACHIEVING MODULAR COMMONALITY VIA A RECONFIGURED CONVERTER IN A 10kW POWER CONDITIONER...

New 6-SCR Converter

28-SCR Production Inverter



10kW Power Conditioner
Input – 220/380V, 50Hz, 240/416V, 60Hz, or 400Vdc
Output – 120/208V, 400Hz, 10kW, 0.8pF
Line Current Harmonics (THD) – <3 percent
Volume – 10 cubic feet
Weight – 360 pounds

...& IN 1983, A COMMON MODULE REPLACEMENT FOR DELCO'S 28-SCR INVERTER.

Figure 5. Power Conditioner Evolution — The Ultimate Goal is a Common Circuit Topology for Power Conditioners of Any Size

existing MEPDIS cable designs and use of common distribution centers, engine generator controls and network controllers for either 60 Hz or 400 Hz distribution systems. Power conditioners (frequency changers) presently being specified for Army development must provide multiple output frequencies and could contain the necessary microcomputers for interface with the DoD standard distribution network.

Power Conditioning

Through IR&D and contract supported effort Delco is providing concepts, prototype units and production hardware aimed at meeting the stated DoD need for power conditioner units. The approach is to build upon previously demonstrated achievements while working closely with user agencies to compose specifications that reflect state-of-the-art developments in the solid state power field. Figure 5 illustrates this evolutionary approach, the basis for our 1981-1982 objective of achieving commonality through a common module.

The power conditioner for MEP-D423A (Figure 5) helped satisfy an urgent need for a very light weight generator to power the Army's TPQ-36 mortar locating radar. Although the inverter uses 28 identical SCR's, the approach does not result in internal power module commonality. The 12-SCR converter shown made tremendous advances in achieving low input line current THD at very light weight, and great strides in providing power module commonality. Three identical 4-SCR converters are used (one per input phase) and the SCR's are common to those in the 28-SCR inverter.

The 28-SCR inverter concept and 12-SCR converter were combined as a prototype 15 kW, 60/400 Hz frequency changer. The importance of this integration is reflected in the Army's New Purchase description for a 10/15 kW Power Conditioner being released for competitive bid as the first member in an Army "Family of Power Conditioners". Key parameters of the new specification are shown in the table of Figure 5 which compares those competing designs known to have addressed the difficult harmonic current THD requirement. The comparison shows a Delco weight advantage and lower power switch device count.

Delco's present high SCR count is due to lack of modular commonality between the inverter and converter functions. Therefore, Delco's IR&D technology thrust is toward common power modules and common control modules for both the inverter and converter functions, and a circuit topology applicable over the entire power range of interest to DoD users. The final column of the table in Figure 5 is an estimate of what can be achieved upon successful completion of the present IR&D effort.

The common module effort centers on expansion of previous Delco resonant converter designs to include the functions shown in the block diagram of Figure 5. The power circuit has a high frequency resonant inverter (SCR's Q_1 and Q_2) operating in a PFM mode to produce the waveforms shown at the output of the high frequency transformer, T_1. A bridge inverter (SCR's Q_3 through Q_6) operates as a 60 Hz or 400 Hz demodulator of the resulting PFM/PAM wave when the common module operates as a frequency changer. A 4-diode rectifier demodulates the high frequency waveform when operating as a converter.

During MY81 Delco successfully demonstrated the 2-SCR converter operation depicted by the upper waveforms in the block diagram. This year we will concentrate on optimizing the 2-SCR common module by increasing operating frequency from 8 kHz to 16 kHz and output power from 3.5 kW to 6 kW. This will include completion of a breadboard "universal" power circuit test fixture and control and evaluation of state-of-the-art materials, components and devices in the fixture. After optimizing converter performance, the fixture will be used to demonstrate the inverter mode with the 2-SCR controls.

Upon optimizing the 2-SCR converter common module, hardware development of a 10 kW power conditioner will be initiated as a first step to demonstrating commonality and logistic benefits which accrue to the common module concept. The approach is to integrate a 6-SCR converter configuration (three 2-SCR common modules) with a 28-SCR production inverter (procured during 1981) which is presently in the Army's logistics system. The unit will further demonstrate capability to operate from U.S. and European high voltage inputs and applicability to solar cell, battery, or fuel cell dc voltage inputs. The unit will, in 1983, serve as a vehicle to demonstrate the common module replacement for Delco's present 28-SCR inverter.

MY82 Planning and Task Definition

Figure 6 shows our detailed plan for MY82 in the form of a Summary Task Table. This table provides an expansion of the previously stated Objectives, detailed task structure, technical approach, work efforts/methods/special items required. and anticipated results of each task. It also serves as an evaluation tool for assessment of Delco's plans, objectives, approach and allocation of resources (skills and time span) to MY82 Power Distribution and Control, Common Module Development and Power Conditioner Development.

PROGRESS

Power Distribution

The Phase II Advanced Development Unit Demonstration effort was not initiated until late in MY81. Before release of funds for the feasibility demonstration hardware, Delco met a related technology contractual commitment to the Army to develop and demonstrate a paralleling controller for the prototype 15 kW power conditioner unit. This goal was completed via a sell-off demonstration to MERADCOM in January 1981 and submission of the final report in March 1981.

From September 1980 to March 1981, Delco continued its military needs analysis and interface with tri-service users to establish the viability of our power distribution concepts and the potential for Government funded follow-on. Success with the paralleling controller, coupled with favorable user community comment, led to a Delco management decision to proceed with the proposed MY81 effort in June 1981.

In this manner, the original MY81 effort was shifted to encompass the last three months of MY81 and first five months of MY82. The Phase II effort required approximately the same total manpower and resource commitments as originally planned.

The summary progress table in Figure 7 shows the progress made during the last three months of MY81. The controller concept has been detailed and laboratory model has been built which will be used to test "status display" and "control" scenarios. Figure 8 presents an example of a typical network scenario.

AREA	1982 OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	GENERAL APPROACH	INPUTS REQUIRED	PROCESS OR METHOD	OUTPUTS EXPECTED	SPECIAL EQUIPMENT/ CAPABILITIES REQUIRED	REQUIRED SKILLS/TIME	RELATIONSHIP TO OTHER TASKS
POWER DISTRIBUTION HARDWARE AND FEASIBILITY DEMONSTRATION	Complete Demonstration Hardware	Integrate Delco "touch screen" CRT hardware into the controller.	Review interface requirements and adapt as needed.	• CRT hardware • Design drawings, schematics, and specifications.	• Analyze electrical interfaces • Design adaptive connections • Fabrication and checkout.	Highly flexible, easy to use operator display and control unit.	Delco "touch screen" CRT and documentation from other Delco programs.	Engineering, 0.5mm Shop, 0.2mm 1.5 month span time Sep 81 through mid-Oct 81	Integrated CRT and controls used in all tasks below.
	Complete Control and Display Software	• Complete fiber optics communications software • Develop display, operator interface, and distribution control software.	• Analyze data and rate transfers and incorporate • Adapt Delco CRT display software to new requirements and expand existing algorithms.	• Communications detail requirements from 1981 effort • Basic Delco CRT display software • New expanded control and display specifications.	• Adapt previous protocol and signal conventions to increased rates • Iterative modify and checkout approach to expanding existing software to meet needs.	• Solid foundation for expansion of fiber optics links to total system • Power system remote control, data acquisition and diagnostics software adaptable to any expanding network requirements.	• Communications software from 1981 • Purchased optics and interface electronics • Previous Delco-developed software • Detailed system requirements • Microcomputer compatible logic analyzer (HP1611).	Engineering, 1.5mm 2.0 month span time Sep 81 through Oct 81	Checked out software used in all tasks below.
	Integrate Control Hardware with GLP Power Equipment	• Checkout all controller elements in Power Lab • Complete integration of demonstration distribution network.	• Power Lab bench setup and test of controller • Integrate with GLP power conditioner and distribution center.	• Controller hardware and software • Power equipment interface definition • Checkout and test plan.	• Use Power Lab equipment to simulate GLP for initial checks • Move to actual GLP units at low volts and power • Advance to full voltage and power.	• Integrated and functional power distribution controller system • Checked out and refined control algorithms.	Delco Power Lab facilities and test equipment compatible logic analyzer (HP1611) GLP 15kW power conditioner and paralleling unit.	Engineering, 2.0mm Technician, 1.5 mm 2.0 month span time Late Oct 81 through Nov 81	Integration and checkout of requirements for task listed below.
	Total System Evaluation and Demonstration	• Evaluate system performance • Demonstrate performance.	• Conduct system level tests • Tri-Service user demonstration at Delco.	• Complete and check out system • System test plan • Demonstration plan.	• Perform system test using both utility, 400 hertz motor generator and GLP 15kW frequency changer. • Provide technical briefing and demonstration.	• Detailed performance data • Achieve Government-funded follow-on.	Special equipment and capabilities as listed in task above.	Engineering, 1.0mm Technician, 0.5 mm 2.0 month span time Dec 81 through Jan 82	Results and feedback needed for task listed below
	Provide Final Report	• Data collection • Technical evaluation • Establish follow-on system specification.	• Analysis of data and review comments • Assimilate, summarize, and record.	• Design data • Test data • Review inputs • Tri-service system specification consensus.	• Engineering and system analysis • Delco management review • Tri-Service review.	• Final report • Basis for follow-on Government-funding.	Special equipment and capabilities as listed in task above.	Engineering, 0.5mm 1.0 month span time January 82	Basis for Government funded follow-on work

Figure 6 (Sheet 1 of 3). Summary Task Table

DEVELOP COMMON POWER MODULE AND CONTROL MODULE TOPOLOGY

1982 OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	GENERAL APPROACH	INPUTS REQUIRED	PROCESS OR METHOD	OUTPUTS EXPECTED	SPECIAL EQUIPMENT/ CAPABILITIES REQUIRED	REQUIRED SKILLS/TIME	RELATIONSHIP TO OTHER TASKS
Select Power Components, Devices, and Materials	Evaluate 1981 procured state of the art devices/materials.	Validate supplier specification	• Data sheets and/or supplier specifications • Supplier's test methods and procedures • Test set-up and plan • Designs for fabricated components.	• Electrical/thermal test and measure • Fabricate and test special components • Correlation to specification.	Selection of components and devices for use at high voltage, high power, and high frequency.	• State-of-the-art items from 1981 • Delco's Power Lab, fixtures, test equipment and talent.	Engineering, 0.5mm Technician, 0.3mm 3 month time span from Sep through Nov 81.	Selected, tested devices and components used in all tasks listed below
Complete Universal Power and Control Circuit Test Fixture	• Incorporate power circuit magnetics • Add control circuit error amplifiers.	Integrate laboratory breadboard magnetics and error amplifiers with 1981 fixture.	• Inductor and transformer specifications • Detailed magnetics designs • Error amplifier input/output specifications • Detailed circuit design.	• Technician—build; engineering—evaluate magnetics • Technician—build; engineering—evaluate CCA's • Technician—integrate with 1981 fixture • Engineering—checkout.	• Low density, well-cooled universal power circuit fixture • Universal control circuit card file with PWB, card edge connector CCA's.	• Techniques to minimize stray L's • Litz wire fabrication techniques.	Engineering, 0.5mm Technician, 2.2mm Shop, 0.2mm 2 month time span: from Sep through October 81.	• Incorporate the state-of-the-art tested components (above) • Provides functional power circuit fixture and controls for all tasks listed below.
Optimize 2-SCR Converter Module	• Develop high voltage input circuit • Double the operating frequency of module • Double the DCV output power.	Incorporate state-of-the-art power devices and materials.	• Tested state-of-the-art devices and materials • High voltage power circuit design • Detailed circuit and component design iterations.	• Iterative test and modify process • Empirical design mods to reduce stray inductance • Measure and record thermal and electrical data.	• Breadboard of 2-SCR converter and controls: – Input: 380 or 416Vac single ϕ, or 400Vdc – Output: 300Vdc, 0 to 20 amps, 6kW – Efficiency: > 93% – Power module frequency: to 16kHz – Line I THD: < 3%	• Universal test fixture • 2-SCR design from 1981 • Knowledge of high power frequency techniques.	Engineering, 1.5mm Technician, 1.0mm 2.5 month time span: from Nov 81 through mid-Jan 82. $18,400, material	• Incorporate the state-of-the-art tested components (above) • Provides basic common module approach for all tasks listed below and 10kW power conditioner build.
Demonstrate DC-to-AC Inversion	• Develop required mods to converter power circuit • Develop inversion control circuits • Integrate and test.	Modify 2-SCR converter module and controls to provide inversion.	• Design mods to power and controls from ac-to-dc converter • Amplitude/phase ref circuit design and CCA layout • 4-SCR demodulator and filter control/power circuit designs and layouts • Energy return circuit and controls—designs and layouts.	• Technician—build; engineering—evaluation of designs • Technician—integration; engineering—evaluate system • Iterative test and mod of demodulator and energy return control and power circuits.	• Breadboard of 2-SCR inverter and controls: – Power demodulator and output filter – DC to 120Vac, 60 or 400Hz – Specifications and designs for energy return circuits.	• Universal test fixture • Delco-developed SCR monitor and protection circuit designs.	Engineering, 3.0mm Technician, 3.0mm Shop, 1.0mm 5 month time span. from Jan 82 through May 82.	• Incorporate the state-of-the-art tested components (above) • Utilizes Universal Power Test Fixture and controls • Mechanical and thermal inputs directly relate to the task listed below
Integrate Converter and Inverter Functions	• Develop common power circuit module • Develop common control circuits • Develop mechanical and thermal design • Fabricate, integrate, and test.	Expand and modify above converter and inverter breadboard designs.	• Design mods to converter and inverter control circuits • Output demodulation and rectifier designs • Common high frequency module design. • Energy return, circuit design.	• Technician—build; engineering—evaluation of designs • Technician—integration; engineering—evaluate system • Iterative test and modify.	• Breadboard of 2-SCR common power modules/controls: – Input: 380 or 416Vac single ϕ, or 400Vdc – Output: 120Vac, 1ϕ or 300Vdc at 6kW – Efficiency: > 90% – Power module frequency: to 16kHz – Line I THD: < 3%	• Modified universal power module fixtures • Modified universal card file and control circuit card assemblies.	Engineering, 1.0mm Technician, 2.0mm Shop, 0.2mm 3 month time span: from May 82 through Jul 82.	Lays essential ground work for 1983 IR&D.

Figure 6 (Sheet 2 of 3). Summary Task Table

10kW POWER CONDITIONER DEMONSTRATION HARDWARE

1982 OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	GENERAL APPROACH	INPUTS REQUIRED	PROCESS OR METHOD	OUTPUTS EXPECTED	SPECIAL EQUIPMENT/ CAPABILITIES REQUIRED	REQUIRED SKILLS/TIME	RELATIONSHIP TO OTHER TASKS
Provide Advance Development Unit 10kW Frequency Changer	System packaging design.	Extend modular packaging of prior Firefinder and 15kW Frequency Changer contracts.	• Mechanical layouts for inverter, converter, auxiliaries, and control CCA's • Monitor/display requirements • Device dissipation • Thermal requirements.	• Thermal analysis • Iterative mechanical/electrical/thermal layout • Maintainability review • Human factors review.	• Packaging, layout, and engineering drawings • Cooling specifications • Controls and display engineering drawings • Electrical and mechanical interfaces defined.	• Packaging experience of previous Delco/Army designs • 28-SCR Army Firefinder Inverter built in 1981.	Engineering, 1.0mm Technician, 0.5mm 2 month time span. from mid-Nov 81 through mid-Jan 82.	Results essential to all tasks outlined below.
Demonstrate Integration of Converter Common Module with Existing Army 28-SCR Inverter	Develop three 2-SCR converter modules and controls.	Package three 2-SCR converters and controls using optimized design from common module development task.	• Packaging constraints • Power circuit design update • Control circuit design update • Tested components.	• Engineering design • Technician—build; engineering—evaluation of components and modules and CCA's • Technician—integrate; engineering—checkout three converters and controls.	Three 2-SCR converter modules and controls: – Input: 380 or 416Vac 3φ, or 400Vdc – Output: 300Vdc, 0 to 40 amps, 12kW – Efficiency: > 93% – Line I THD: < 3%	• 2-SCR design from 1981 • Design update from 2-SCR optimization task.	Engineering, 0.5mm Technician, 1.5mm Shop, 0.5mm 2.5 month time span: from mid-Dec 81 through Feb 82.	Converter used in final system integration.
Demonstrate Evolution of Advance Power System using Existing Army Logistic Items	Develop system controls and auxiliary supplies.	Update Delco/Army 15kW Frequency Changer controls and auxiliary supply designs.	• Control and circuit design modifications • Commutation supply design modifications • Low voltage supply modifications • Mechanical design layouts.	• Engineering—design modifications • Technician—build; engineering—evaluate supplies and circuit card assemblies • Technician—integration; engineering—checkout.	• Modular packages of all low level and auxiliary supplies • Control circuit card assemblies and harnesses • Mechanical and electrical interconnections • Engineering sketches and schematics	• Drawings and schematics from previous Delco/Army development • Army 10/15kW draft purchase descriptions and specifications.	Engineering, 1.5mm Technician, 2.0mm Shop, 0.5mm 2 month time span: from Feb 82 through Mar 82.	• Auxiliary supply modules and controls used in final system integration • Establishes new control/circuit designs for Army 10/15kW power conditioner.
Incorporate New Army 10/15kW Control Specifications and Features	Fabricate, assemble and test integrated system.	Implement packaging design and layout.	• Interface modifications to 28-SCR inverter • Finalize electrical and mechanical drawings • System harness and interconnect design • Control/display design and wire layout • Fan/filter design and wire layout • Test plan and procedures.	• Engineering design • Technician—build; engineering—evaluate subsystems • Technician—integration; engineering—checkout • Technician and engineering – test, record, and evaluate system.	• Advance Development Unit 10kW Frequency Changers: – Input: 300 or 416Vac 3φ, or 400Vdc – Output: 120/208Vac, 400Hz, 10kW – Efficiency: > 82% – Line I THD: < 3% • Parts and modules common to present Army Logistics System.	• 28-SCR Army Firefinder Inverter • 2-SCR common module converter • Common module control circuits design • Parts and modules common to present Army Logistics System.	Engineering, 1.0mm Technician, 2.5mm Shop, 0.5mm 3 month time span: from Apr 82 through Jun 82.	• Provides Delco IR&D Unit for 1983 demonstration of: – Solar cell input – No-break and battery input – Fuel cell input • Paralleling demonstration with Delco/Army 15kW unit • Integration and demonstration with Power Distribution Network Engineering Development Unit.

Figure 6 (Sheet 3 of 3). Summary Task Table

Power Conditioning

In MY81 significant progress was made in common power module and common control module development which benefited greatly from a General Motors Corporation solid state power program initiated at Delco during the year. The GMC program centered around developing a 2-SCR converter to charge the high voltage battery of developmental electric automobiles. Success to date in that program makes it unnecessary to optimize 4-SCR converter modules as originally planned for MY81 IR&D. The GMC effort also resulted in a new passive input line current harmonic reduction technique (Figure 9) which will be applied to future military power conditioners applications. This new technique offers several advantages over traditional approaches, including:

- Improved power factor and power utilization
- Greater converter efficiency
- Improved input and/or output voltage accommodation ranges
- Simple low cost mechanization
- Adaptability to active feedback and control for lower THD performance
- Adaptability to previous three-phase mechanization for performance range improvement

Initial efforts in MY81 to specify and procure state-of-the-art components, devices and materials for use in optimizing resonant converter power modules and controls made it clear that the low quantity costs would exceed the allocated material dollars, and that promised dates of delivery for critical items would preclude completion of all tasks. Therefore, a decision was made to perform necessary concept engineering to allow placement of critical item purchase orders for the planned MY82 IR&D, as well as the current year IR&D. The added design and procurement was associated with 1982 plans to optimize and to develop the integrated inverter/converter common module and to develop a 10 kW power conditioner utilizing 1981 achieved commonality concepts. The MY81 program was projected at 10 manmonths and $8,800 for materials. For the reasons discussed above, actual expenditures were 9.2 manmonths effort and $46,000 was comitted for materials with $32,100 being received in MY81.

AREA	1981 OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	TASKS INITIATED IN 1981	TASKS ACCOMPLISHED IN 1981	PLAN DEVIATION AND RATIONALE	SIGNIFICANCE OF ACCOMPLISHMENTS	SPECIAL EQUIPMENT/ CAPABILITIES REQUIRED	SKILLS REQUIRED	POTENTIAL APPLICATION FOR GOVERNMENT
POWER DISTRIBUTION – MICROCOMPUTER CONTROLLER, CONCEPT EVALUATION BREADBOARD	Application of microcomputer technology to centralized power distribution control.	Establish power distribution system control requirements.	• Analysis of power distribution systems control approach • Review of 1980 control study report feedback and comments.	• Established initial control and performance requirements • Defined power-to-control electronics electrical interfaces • Incorporated pertinent 1980 study report review comments.	Additional time was allocated to fully interpret and appropriately incorporate all review comments of 1980 study.	Viable concept breadboard to demonstrate and to evaluate remote power distribution control techniques and associated technology.	• User feedback comments of 1980 report • Design documentation for Delco paralleling controller.	Engineering, 0.5mm	
	Design and development of concept demonstration power distribution controller utilizes: • Imbedded microcomputers • Fiber optic communication links • Interactive CRT control and display technology.	Develop microcomputer-based system mechanization.	Design of breadboard controller for concept and technology evaluation.	Breadboard designs completed for: • Remote microcomputer interface unit • Fiber optic communications link • "Touch screen" CRT microcomputer central control and display unit.	Task completed as per plan.	Breadboard hardware designs based on industry standard microcomputer parts and subassemblies compatible with standard bus structure. Delco custom "touch screen" hardware directly incorporated.	Prolog standard bus microcomputer components, HP HFBR-500 fiber optic links, Delco custom "touch screen" CRT.	Engineering, 1.0mm $6,936, material	
		Develop controller display and control software.	• Definition of controller software structure, control algorithms, and data display formats. • Generation of code for: – Remote unit data acquisition and power system interface – Fiber optic link communication – Control and display.	• Established modular software structure, voltage/current/phase control algorithms, and CRT data display screens • Coding and checkout of remote unit software • Initial communication for early checkout developed.	Task initiation paced by review of 1980 study feedback comments, completion of paralleling controller contract item and negotiation of agreement for GLP hardware. Task effort begun July 1981. Remainder carried over into 1982.	Modular software structure allows independent/parallel development of software modules/blocks and facilitates rapid changes with minimum coding impact during system checkout, evaluation, and refinement.	Analytical definition of control algorithms. Human factors assessments of data format and display. Definition of communications protocol between controller and the remotes.	Engineering, 1.2mm	• Applicable to all tactical power networks. • Base and fleet hospitals. • Missile silo power system. • Controller and links apply to shipboard power networks.
	Fabricate complete breadboard power distribution controller.	Laboratory build of one complete set of controller hardware.	Build (2) remote units, (2) fiber optic links, and (1) controller unit with a CRT interface.	Two remote units and two fiber optic links completed. CRT controller in progress.	• CRT controller not complete • Rationale as listed above.	Remote units and fiber optic links checked out.	Controller breadboard hardware with initial communications and display software.	Engineering, 0.2mm Technician, 0.4 mm $450, material	
	Interface breadboard with Delco and GLP power equipment. • System performance evaluation • Concept demonstration.	• Bench integration of controller hardware and software checkout. • Laboratory integration with power equipment and checkout. • In-house and customer demonstrations.	Bench integration of remotes and fiber optic links and checkout.	Partial checkout completed.	Rescheduled to 1982 due to decision to complete paralleling contract item, market survey, review of tri-service inputs and negotiate agreement for GLP 15kW unit and controller.		Controller hardware and software, GLP 15kW power conditioner and GLP paralleling controller unit.		
	Generate final report.	Prepare and distribute final report.					Completion of demonstrations and review of pertinent comments.		

Figure 7 (Sheet 1 of 2). Summery Progress Table

	1981 OBJECTIVES	TASKS REQUIRED TO ACHIEVE OBJECTIVES	TASKS INITIATED IN 1981	TASKS ACCOMPLISHED IN 1981	PLAN DEVIATION AND RATIONALE	SIGNIFICANCE OF ACCOMPLISHMENTS	SPECIAL EQUIPMENT/ CAPABILITIES REQUIRED	SKILLS REQUIRED	POTENTIAL APPLICATION FOR GOVERNMENT
DEVELOP COMMON POWER MODULE AND COMMON CONTROL MODULE TOPOLOGY	Extend 4-SCR Converter Module Capability: – Frequency to 16kHz – Power to 12kW Develop 2-SCR Converter Module: – Frequency to 16kHz – Power to 8kW	Specify, procure, and evaluate state-of-the-art components, devices, and materials for 1981 IR&D.	• Specify and procure state-of-the-art material components and devices for 1981 IR&D • *Conceptual design and parts defined for 1982 IR&D.*	• Specify and place purchase orders (late 1981 receipts) • 1982 concepts specified and parts have been procured (late 1981 receipts).	• $8.8K planned, but $25.5K spent • Lead times and costs much greater than planned • Types and quantities were increased to cover 1982 needs • Defer evaluation due to lead times.	• Good success in identifying and procuring state-of-the-art for 1981 IR&D • Conceptual designs and major parts now defined and procured for 1982 IR&D.	• Vendor data and contacts • Symposia record review and attend • Power circuit stress analysis knowledge.	Engineering, 1.0mm Technician, 0.4mm $25.5K, material	• Army family of power conditioners (frequency changers) • Army Standard Power Processing (Converter) Modules
	Demonstrate DC-to-AC Inversion with Modified 2 or 4-SCR Modules	• Design/fabricate universal resonant circuit fixture • Design/fabricate demodulator/filter fixture.	• Design/fabricate 2- and 4-SCR resonant circuit mount • Design/fabricate 4-SCR or 4-diode demodulator/filter.	• Design/fabrication 80 percent complete • Design/fabrication 90 percent complete.	• Resonant components L's and transformers not developed • SCR's, diodes, and C's not mounted. • Long lead precluded design, fabrication and mounting.	• A well-cooled flexible fixture • Layout for minimum stray L's.	• Experience in power circuit layout • *Knowledge of stray L's and high frequency technique.*	Engineering, 1.0mm Technician, 1.0mm Shop, 0.9mm	• *Navy family of shipboard degaussing power supplies* • Titan II/MX Silo Power Conditioners
		• Develop ac/dc converter controls • Develop dc/ac inverter controls • Develop 4-SCR demodulator controls.	• Design/fabricate converter controls • Design/fabricate inverter controls • Design/fabricate demodulator controls.	• *Design/fabrication 70 percent complete* • *Design/fabrication 75 percent complete* • Design/fabrication 70 percent complete.	• *Error amplifiers and feedback loops not designed/fabricated* • Control circuit talents directed to GMC 2-SCR converter for future electric auto battery charger.	• Major control circuit card assemblies tested, meet design requirements • GMC 2-SCR battery charger controls technology transfer at no IR&D cost.	• Linear and non-linear control system expertise • Control and power circuit interface problem knowledge.	Engineering, 2.2mm Technician, 1.7mm	• Army SLEEPS (Fuel Cell) Power Conditioners • Army/Marine Solar Array Power Conditioners
		• Optimize 4-SCR converter • Develop and optimize 2-SCR converter • Demonstrate dc-to-ac inversion with 2-SCR module.			• Efforts deferred to 1982 • Power Systems engineering talents and lab facilities diverted to GMC 2-SCR, ac/dc converter (battery charger) for the electric auto.	• Similarity of efforts provides important technology transfer at no IR&D cost • 2-SCR battery charger at 3.5kW success obviates need to optimize 4-SCR IR&D converters • Single-phase, Line I harmonic reduction breakthrough applies.			• Military Field and Vehicle *Battery Chargers* • Military welders.
10kW POWER CONDITIONER DEMONSTRATION HARDWARE	Advanced 1982 Planned Effort into 1981	*Develop Advanced Development Unit 10kW Frequency Changer for future IR&D and demonstrations.*	• *Conceptual design of approach* • *Specify and procure long lead parts and materials.*	• Approach defined • Parts and materials ordered and received late 1981.	• Redirected effort planned for the above • Long lead problems dictated early release of items planned for 1982.	• Despite diversion of effort to electric auto, overall 1981 plus 1982 results benefit from technology transfer and critical parts availability.	• Procured 28-SCR inverter and controls from Firefinder production line • Remaining parts from same Army Logistics listing.	Engineering, 0.5mm Technician, 0.5mm $8.8K, material	• Rapid development force power pallets • Integration and demonstration with power distribution network • Paralleling demonstrations with Delco/Army 15kW Frequency Changer.

Figure 7 (Sheet 2 of 2). Summary Progress Table

POWER DISTRIBUTION CONTROLLER

- Breadboard demonstration unit
- Technology implementation vehicle
- Concept demonstration vehicle
- Control system mechanization and algorithm evaluation tool.

TYPICAL *TOUCH SCREEN* OPERATOR SCENARIO

- Function and data display unit surface is touch sensitive
- "Hard keys" are permanently displayed at bottom of screen. These are for major control functions.
- "Soft keys and displays" appear over the remainder of the screen and are variable depending on the operator commands and data.
- Audio (chime) and visual (inverse video) operator feedback for functions selected, control actuation, and status of control functions.
- Scenario:
  1. At system on, the network summary automatically appears and displays complete network status.
  2. Touch hard key "BUS".
  3. "Load Bus Summary" appears.
  4. After examination, touch soft key "Unit No. 1" to continue detailed examination, or for control/adjustment of Unit No. 1.
  5. Power conditioner data and control screen appear. Adjustments and control are now possible from the soft keys on this screen for Unit No. 1. (Unit 1 could have also been selected by touch from the network configuration summary screen. This assures that control access is at most one screen change away.)
  6. Touch hard key "Distribution".
  7. (Not shown). Distribution summary screen appears for data examination.
  8. Touch soft key "Unit No. 9".
  9. Unit No. 9 data and control keys appear. Unit No. 9 has a 10kW engine/generator set source and a 6.7kW load. It is on network standby and ready to parallel. If operator touched network "ON", controller would close paralleling Unit 9 with network. This would automatically be reflected in the network configuration summary ①, and would show Unit 9 as "source" instead of "standby".
  10. If no operator action for 30 seconds, network screen ① automatically appears. (Network can be instantly selected by hard key at any time).

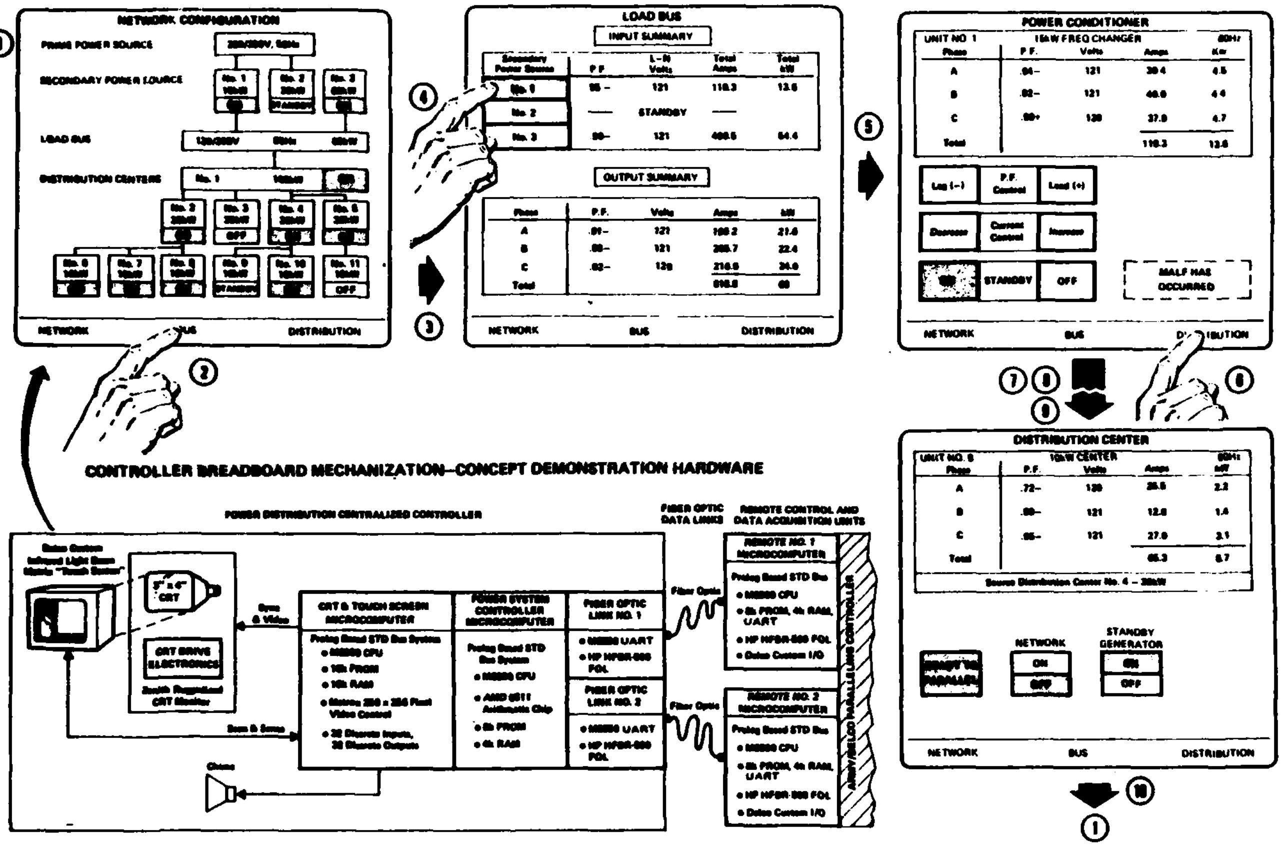


Figure 8. Touch-Screen CRT and Network Control Scenario

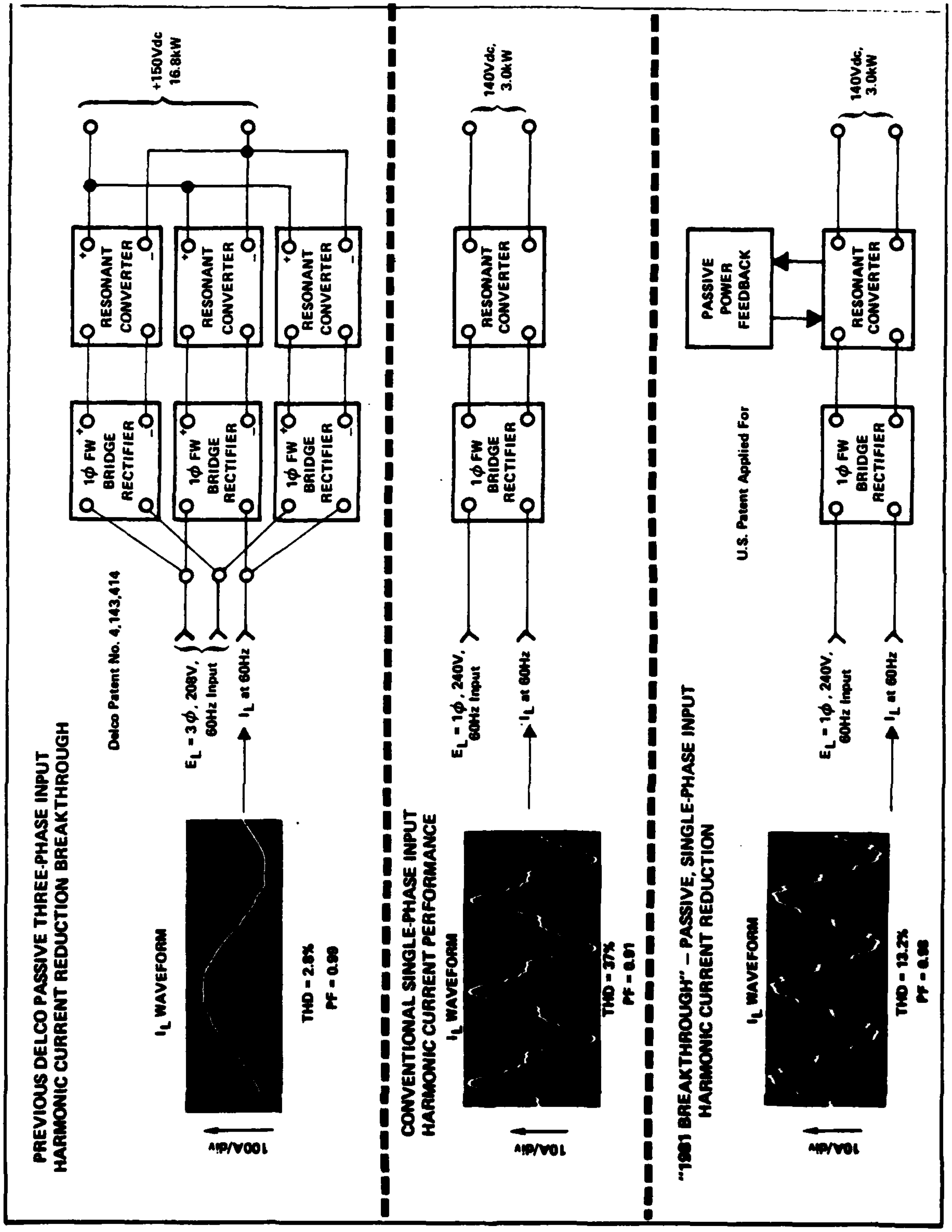


Figure 9. Delco Passive Input Harmonic Current Reduction Breakthrough

SOURCE POWER TRANSFER TESTING

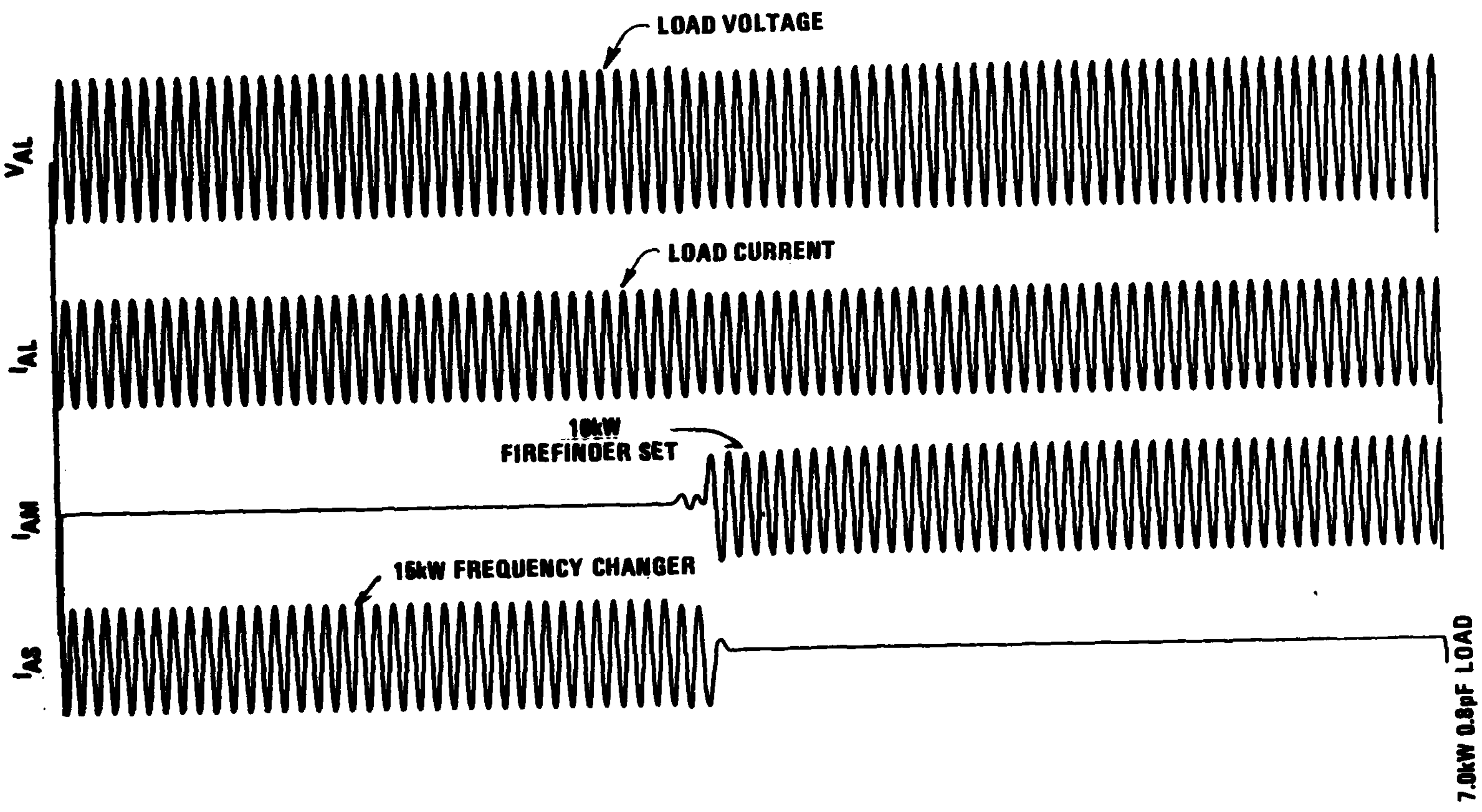
This testing was performed to determine how transient free would be the transfer of power to the bus from Master to Slave and from Slave to Master. For this testing, the Master source was the 10 kW Firefinder Generator Set (MEP D423A). The Slave was the 15 kW Frequency Changer. A rapid transfer was accomplished by simultaneously throwing the Master and Slave contactor switches. There is no provision in the hardware or software to effect a rapid transfer with a single switch operation.

In all the test records the parameters recorded are, from top to bottom, phase A (L1 - L2) bus voltage; phase A (L1) bus current; phase A current from the Master source; and phase A current from the Slave source. Some tests involve the transfer of sources to a 7 kW 0.8 PF load and others to a 11 kW 0.8 PF load.

Test 3-22-01 through test 3-22-04 show the transfer of power source from the 15 kW Frequency Changer to the 10 kW generator set with a 7 kW 0.8 PF load. The only discernable transient is the no load to 7 kW transient load behavior of the 10 kW generator set.

Test 3-22-05 shows the transfer of power source from the 10 kW generator set to the 15 kW Frequency Changer with a 7 kW 0.8 PF load. The only discernable transient is the no load to 7 kW transient load behavior of the 15 kW Frequency Changer.

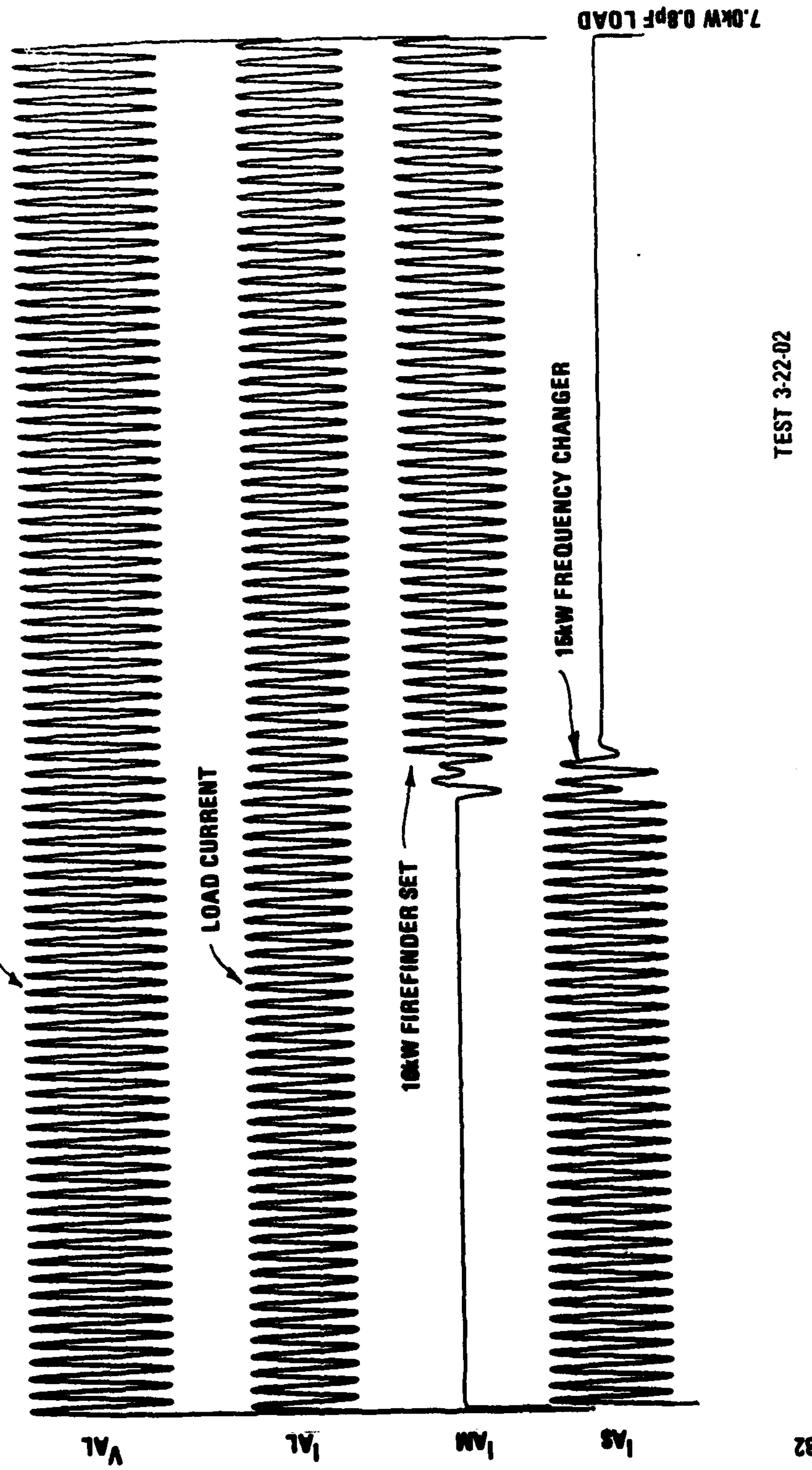
Test 3-22-06 through test 3-22-08 show the transfer of power source from the 15 kW Frequency Changer to the 10 kW generator set with a 11 kW 0.8 PF load. Again, the only discernable transient is the no load to 11 kW transient load behavior of the 10 kW generator set.



TEST 3-22-01

15kW FREQUENCY CHANGER TO FIREFINDER TRANSFER TEST

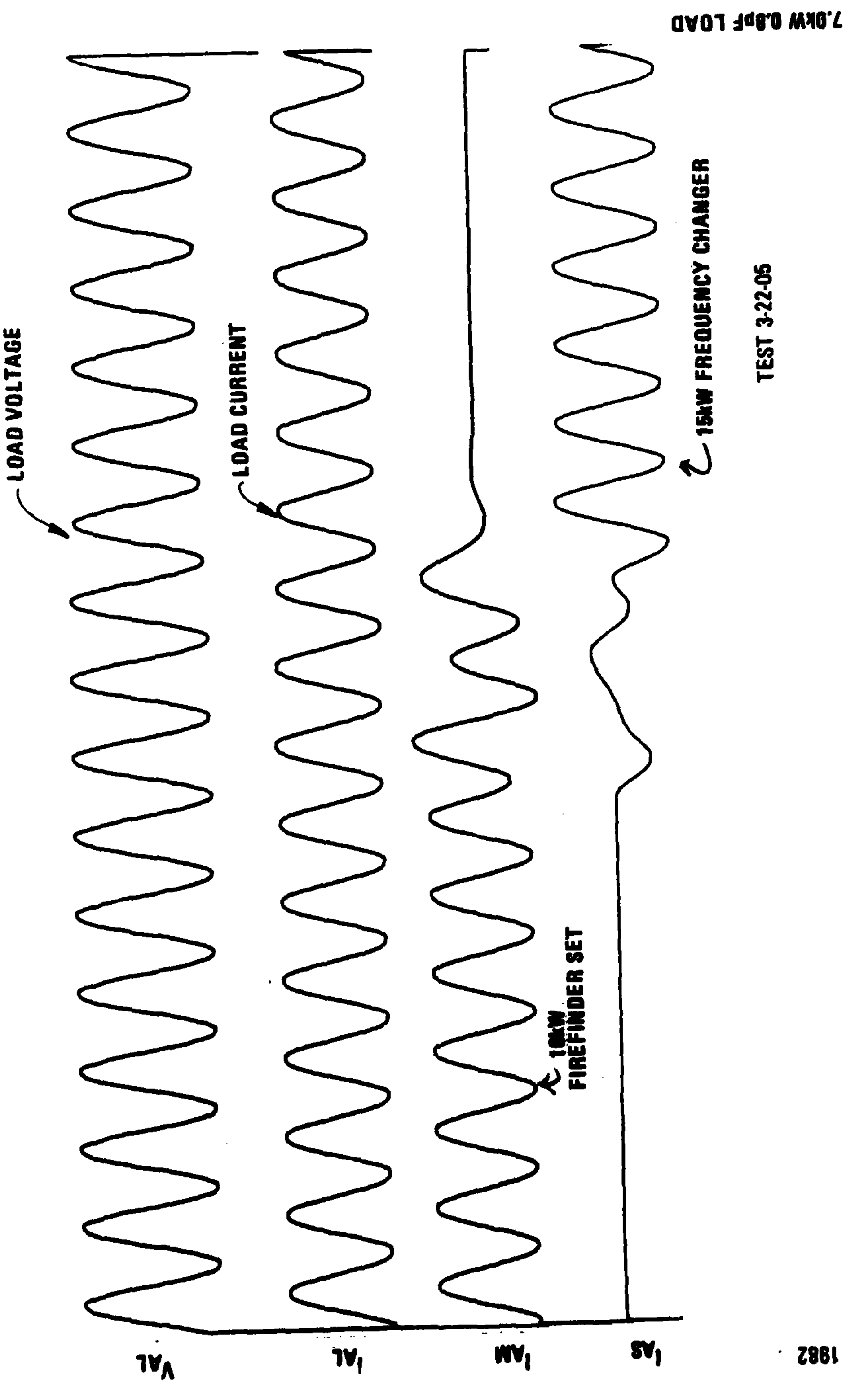
22 March 1982



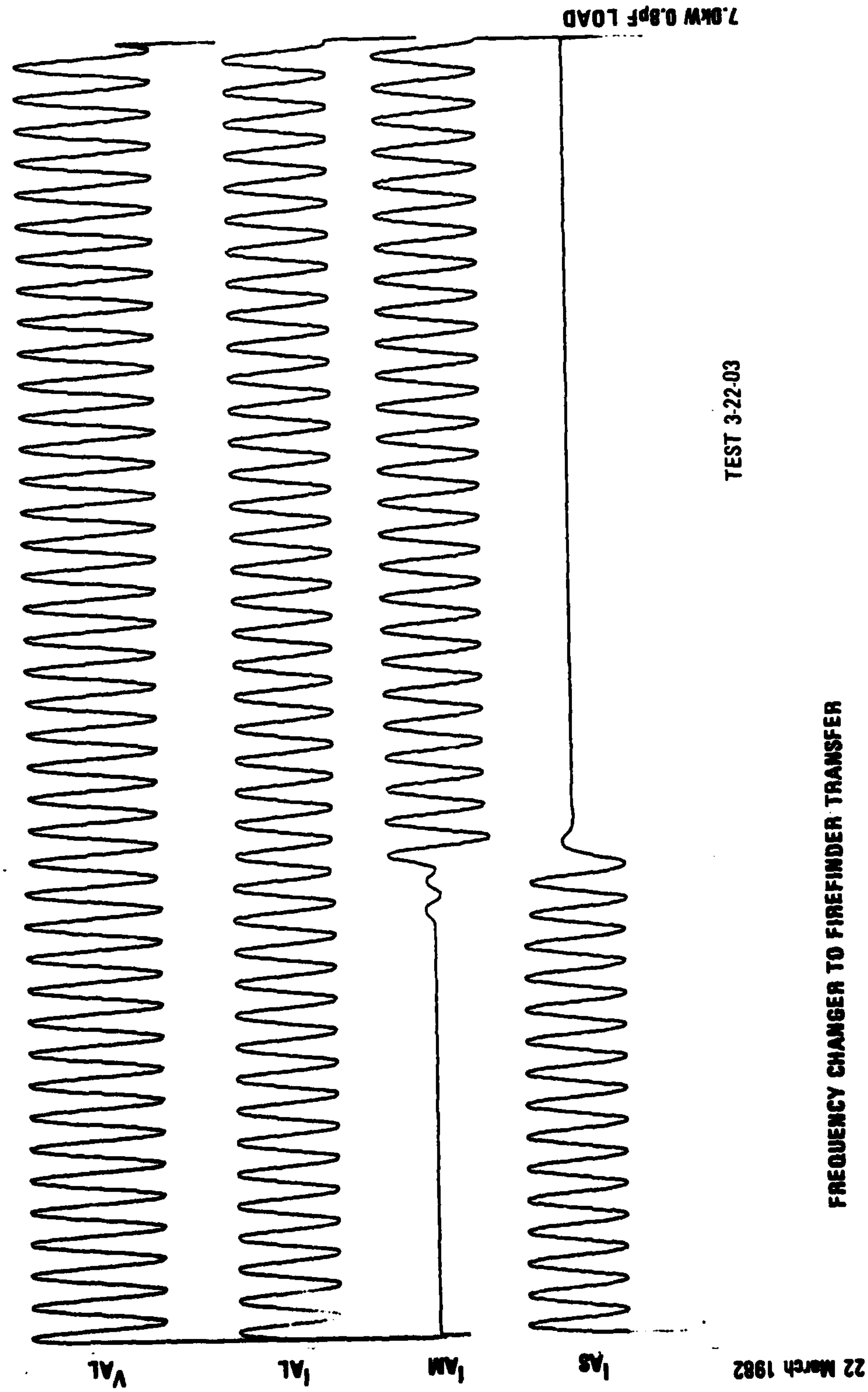
TEST 3-22-02

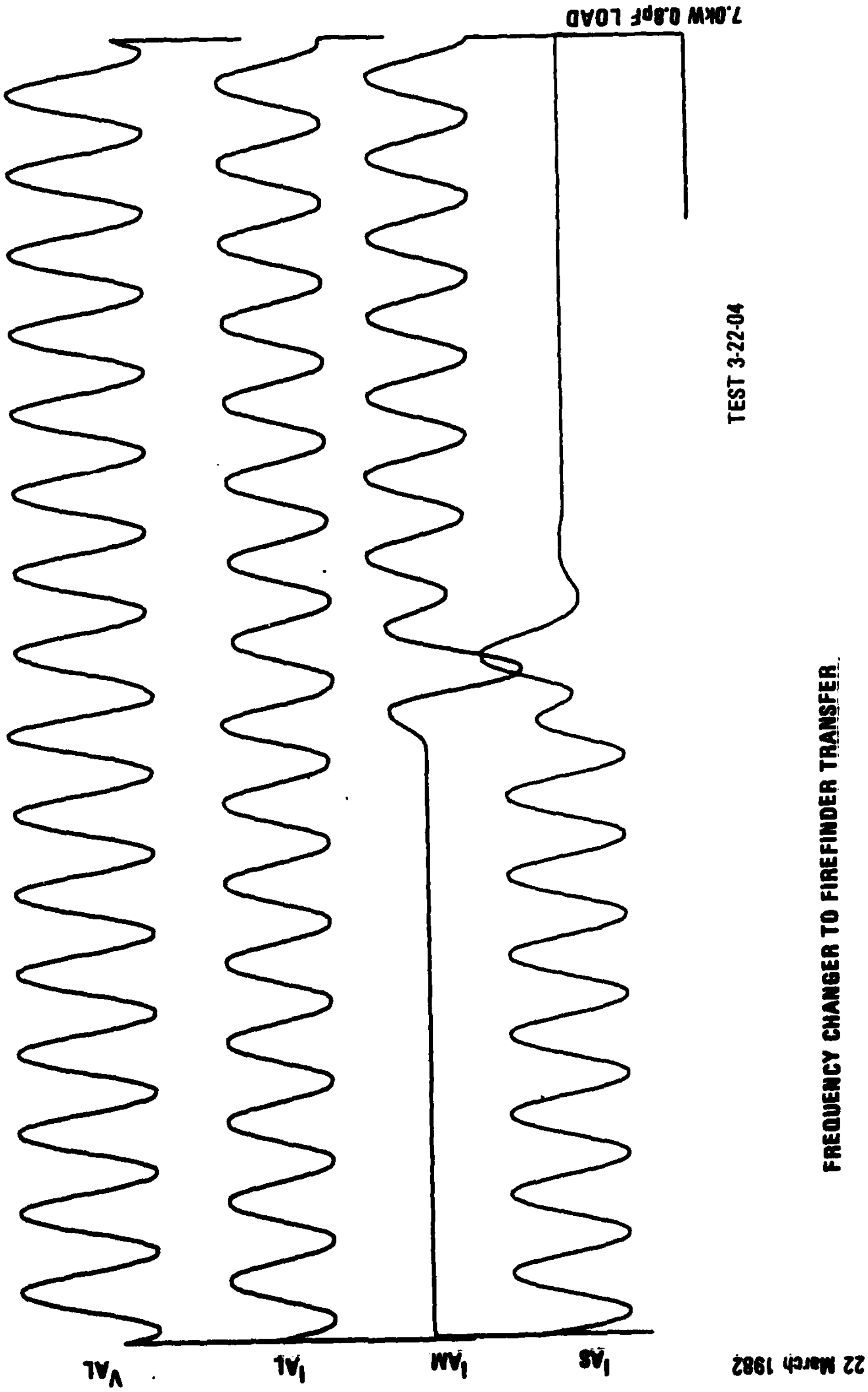
22 March 1982

FREQUENCY CHANGER TO FIREFINDER TRANSFER



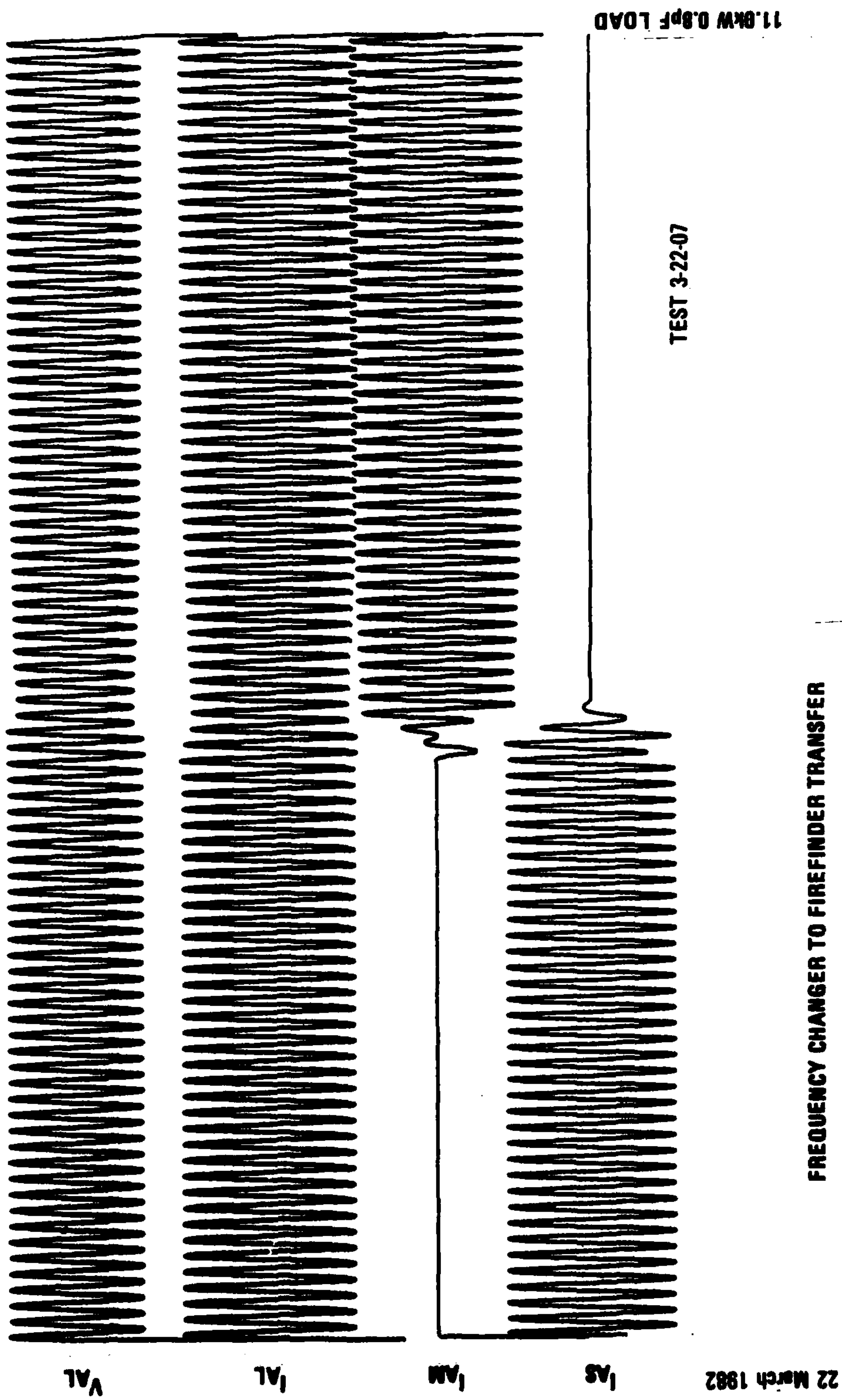
FIREFINDER TO FREQUENCY CHANGER TRANSFER

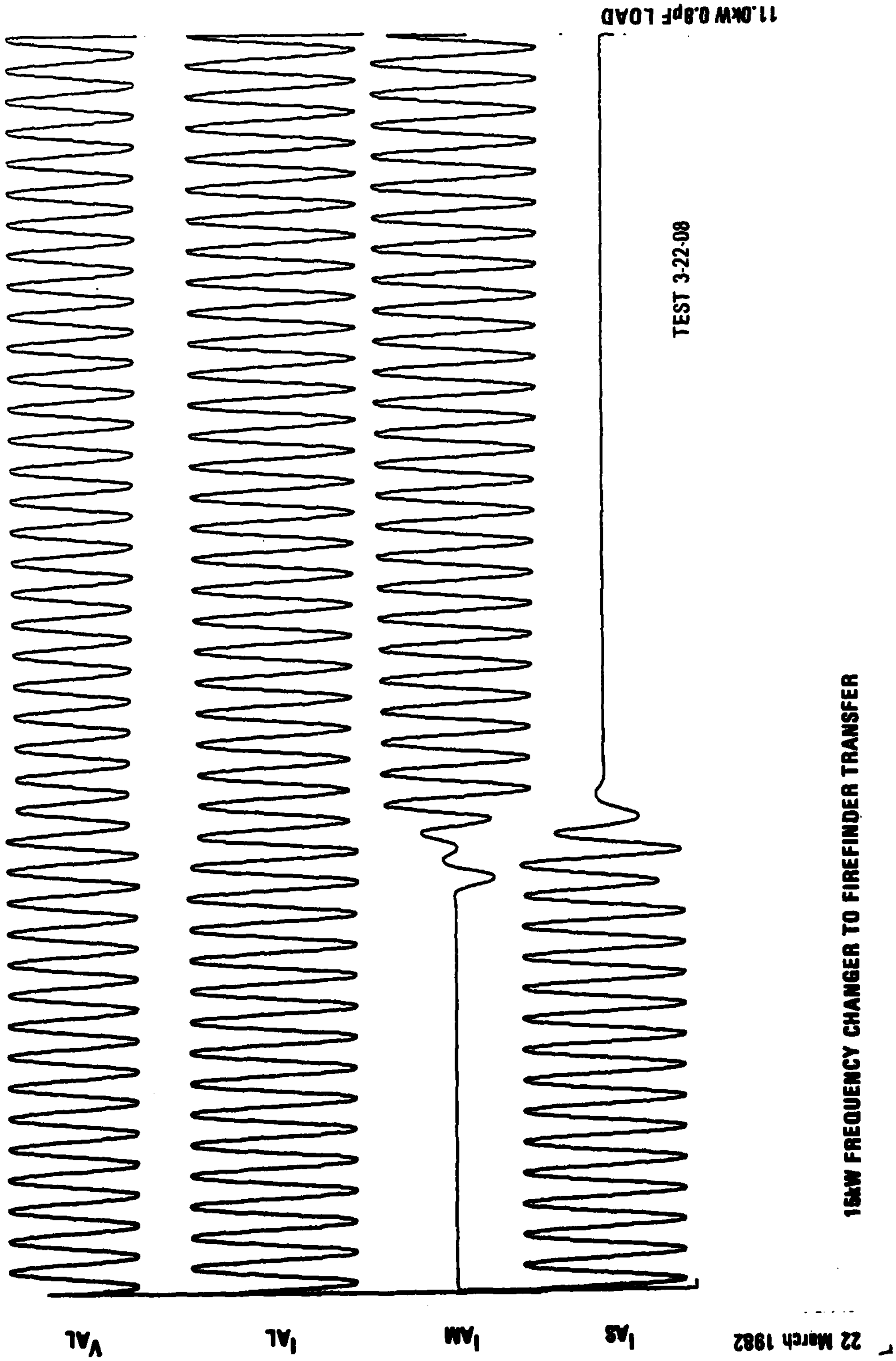

7.0kW 0.8pF LOAD
TEST 3-22-03
FREQUENCY CHANGER TO FIREFINDER TRANSFER
22 March 1982
V_{AL}
I_{AL}
I_{AM}
I_{AS}



FREQUENCY CHANGER TO FIREFINDER TRANSFER


11.0KW 0.8pF LOAD
TEST 3-22-06
FREQUENCY CHANGER TO FIREFINDER TRANSFER
22 March 1982
V_{AL}
I_{AL}
I_{AM}
I_{AS}


11.8kW 0.8pF LOAD
TEST 3-22-07
FREQUENCY CHANGER TO FIREFINDER TRANSFER
VAL
IAL
IAM
IAS
22 March 1982



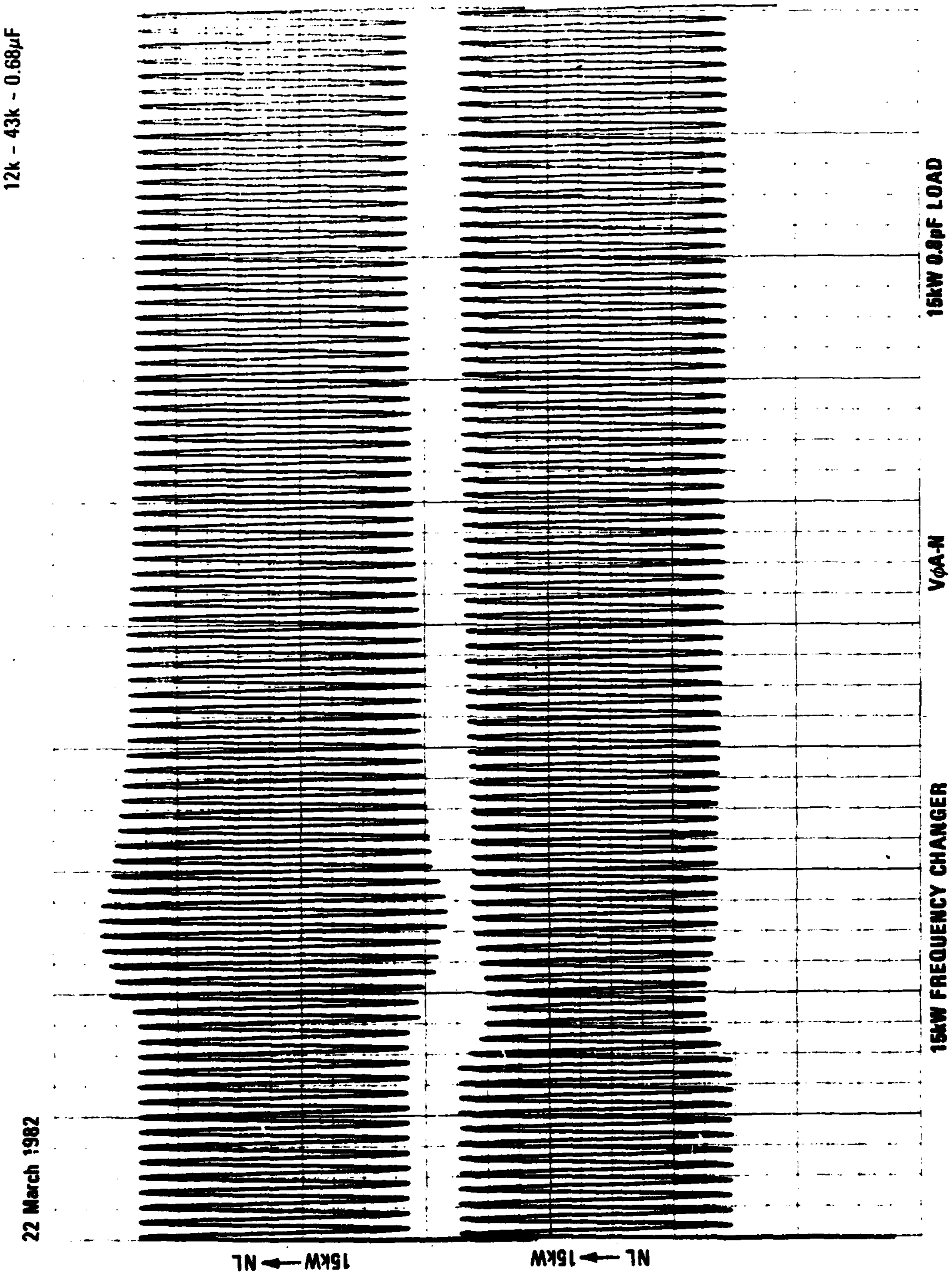
15kW FREQUENCY CHANGER TO FIREFINDER TRANSFER
TEST 3-22-08
11.0kW 0.8pF LOAD
V_{AL}
I_{AL}
I_{AM}
I_{AS}
22 March 1982

15 kW FREQUENCY CHANGER
LOAD CHANGE INDUCED TRANSIENT SIGNATURE

On a power bus being driven by such power sources as motor-generator sets and/or frequency changers individually or in parallel, the load change - induced transient behavior of the sources is seen by the bus loads. This is obviously true in the case of a fixed source configuration operating varying loads. Not so obvious, but equally true, is the case of a fixed load with varying source configuration.

As an example of the later, consider the case where a fixed load is operating on a power bus. If a clean and instantaneous transfer of sources is made from a motor-generator set to a frequency changer, the load change-induced transient behavior of the frequency changer is seen by the load. In this case, the motor-generator set transient appears only at its output terminals after they are unloaded. However, the frequency changer is subjected nearly instantaneously to a no load to bus load transient. In this example, at this point in time, the frequency changer is the only source on the bus; so its transient performance governs the bus performance.

With this in mind, testing was performed on the frequency changer in a stand-alone mode to show its response to step load changers. Much testing of this nature was published in earlier test reports. For convenience and completeness of this report, the results of 1.0 per unit load transient testing are shown here. The upper curve shows the effect of a 15 kW 0.8 PF to no load transient on the phase A (L1 - L0) output voltage. The lower curve shows the effect of a no load to 15 kW 0.8 PF transient on the same output voltage.


12k - 43k - 0.68μF
22 March 1982
15kW 0.9μF LOAD
VφA-N
15kW FREQUENCY CHANGER
15KW → NL
NL → 15KW

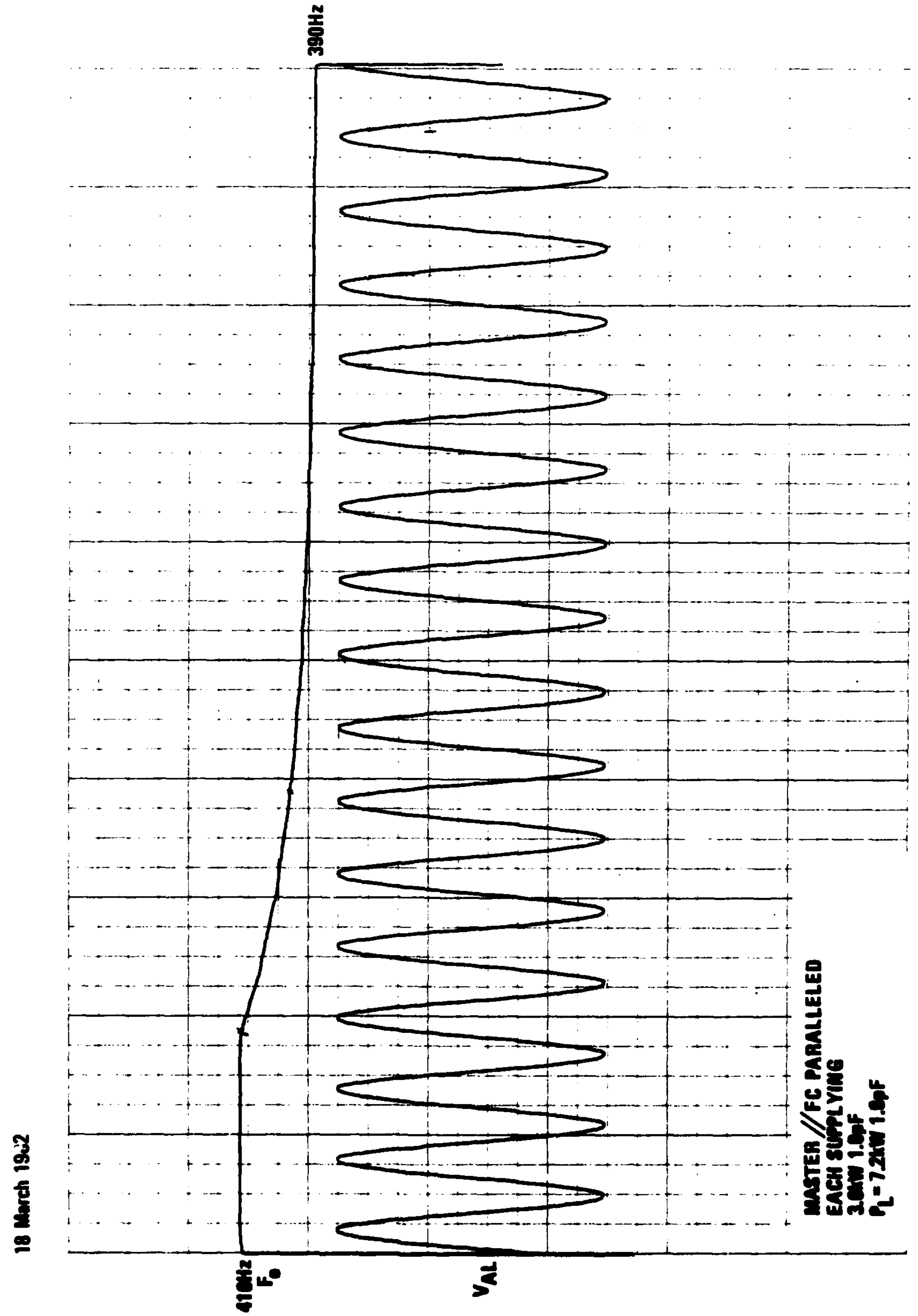
EFFECT OF BUS FREQUENCY CHANGES DURING PARALLEL OPERATION

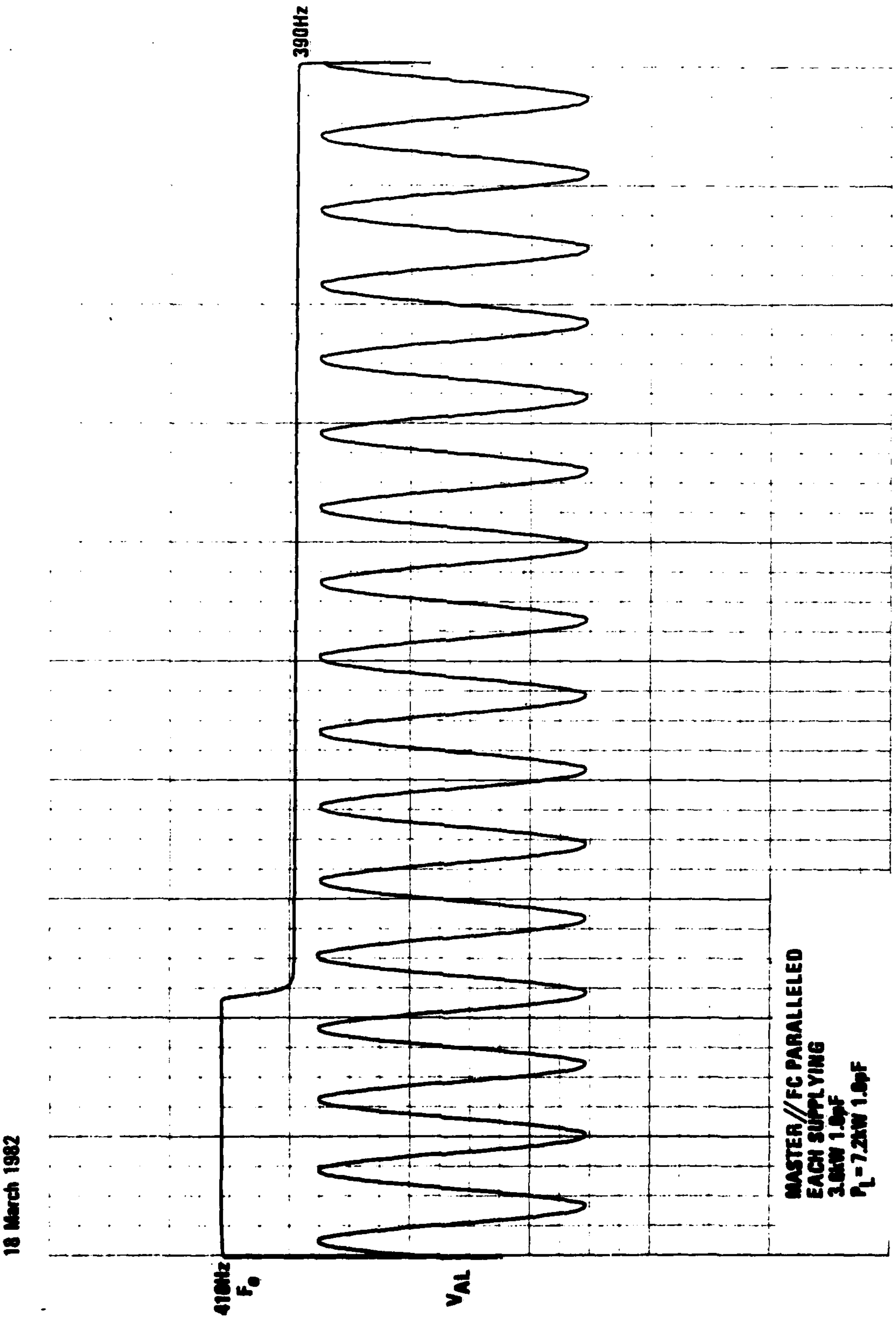
This testing was performed to demonstrate satisfactory operation when the 15 kW Frequency Changer is supplying power to a bus which has a large frequency transient. This might be expected when the Master source is a nonsynchronously driven M-G set and the bus is suddenly loaded.

The Master for this test was the 10 kW Firefinder Generator Set (MEP D423A). It was modified for this test such that its operating frequency could be varied over the range of 390 Hz to 410 Hz. The generator set (Master) and the frequency changer (Slave) were fully paralled and both supplying 3.6 kW to a 7.2 kW, unity PF, load. The phase A (L1 - L0) output voltage at the load was recorded.

In the first test, intended to simulate a typical worst case frequency transient, the Master frequency was varied exponentially from 410 Hz to 390 Hz with a time constant of approximately eight milliseconds. No problem was observed in the phase A voltage waveform.

In the second test, the Master frequency was stepped almost instantaneously from 410 Hz to 390 Hz. Here again, no problem was observed in the phase A voltage waveform. It can be reasonably concluded from these tests that the 15 kW Frequency Changer can be successfully paralleled with a bus having severe frequency transients. Excellent phase locking characteristics have been demonstrated.


390Hz
410Hz
F_o
V_{AL}
18 March 1982
MASTER // FC PARALLELED
EACH SUPPLYING
3.6KW 1.0pF
P_L = 7.2KW 1.0pF



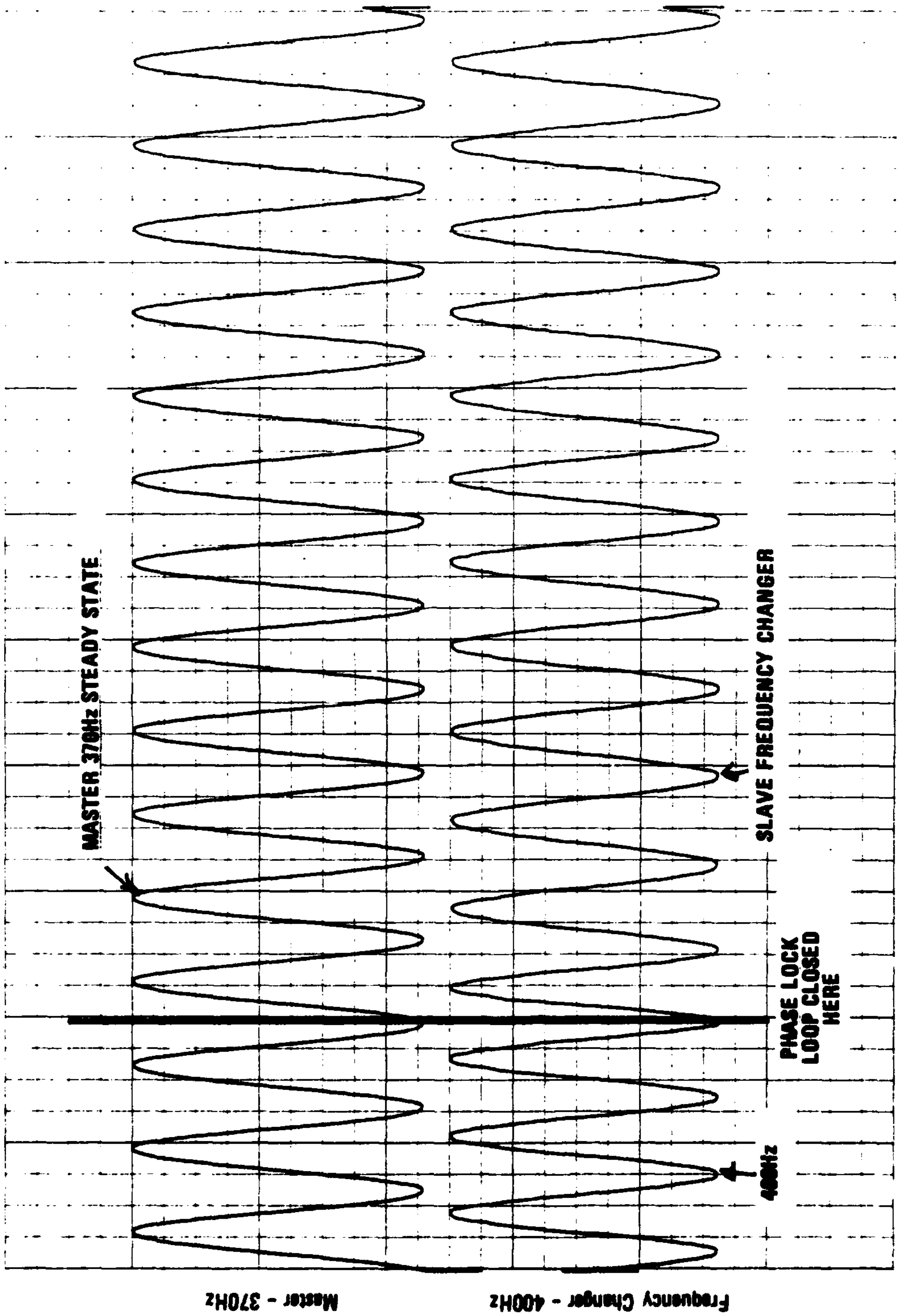
390Hz
18 March 1982
410Hz
F_o
V_{AL}
MASTER // FC PARALLELED
EACH SUPPLYING
3.6kW 1.0pF
P_L = 7.2kW 1.0pF

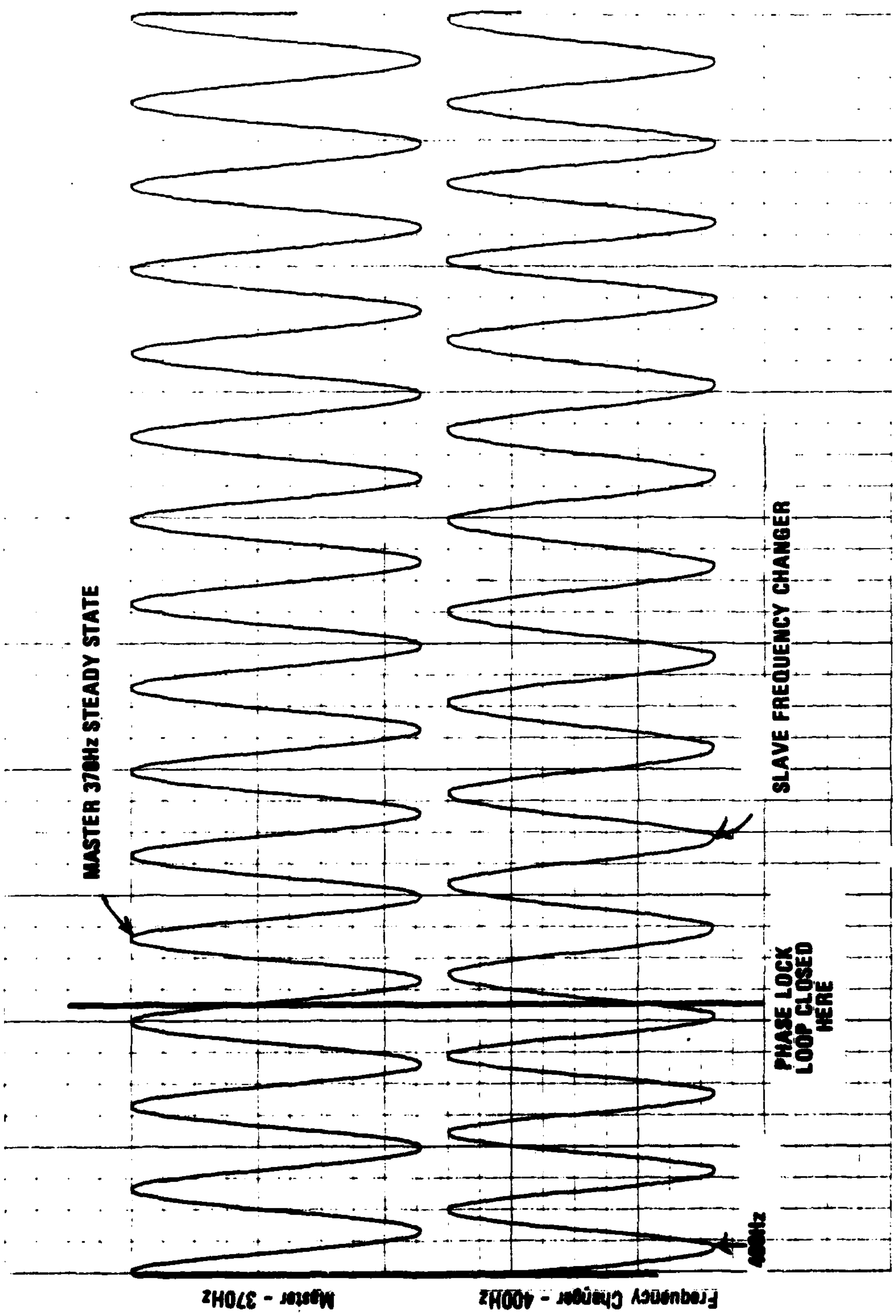
PHASE LOCK CAPTURE BEHAVIOR

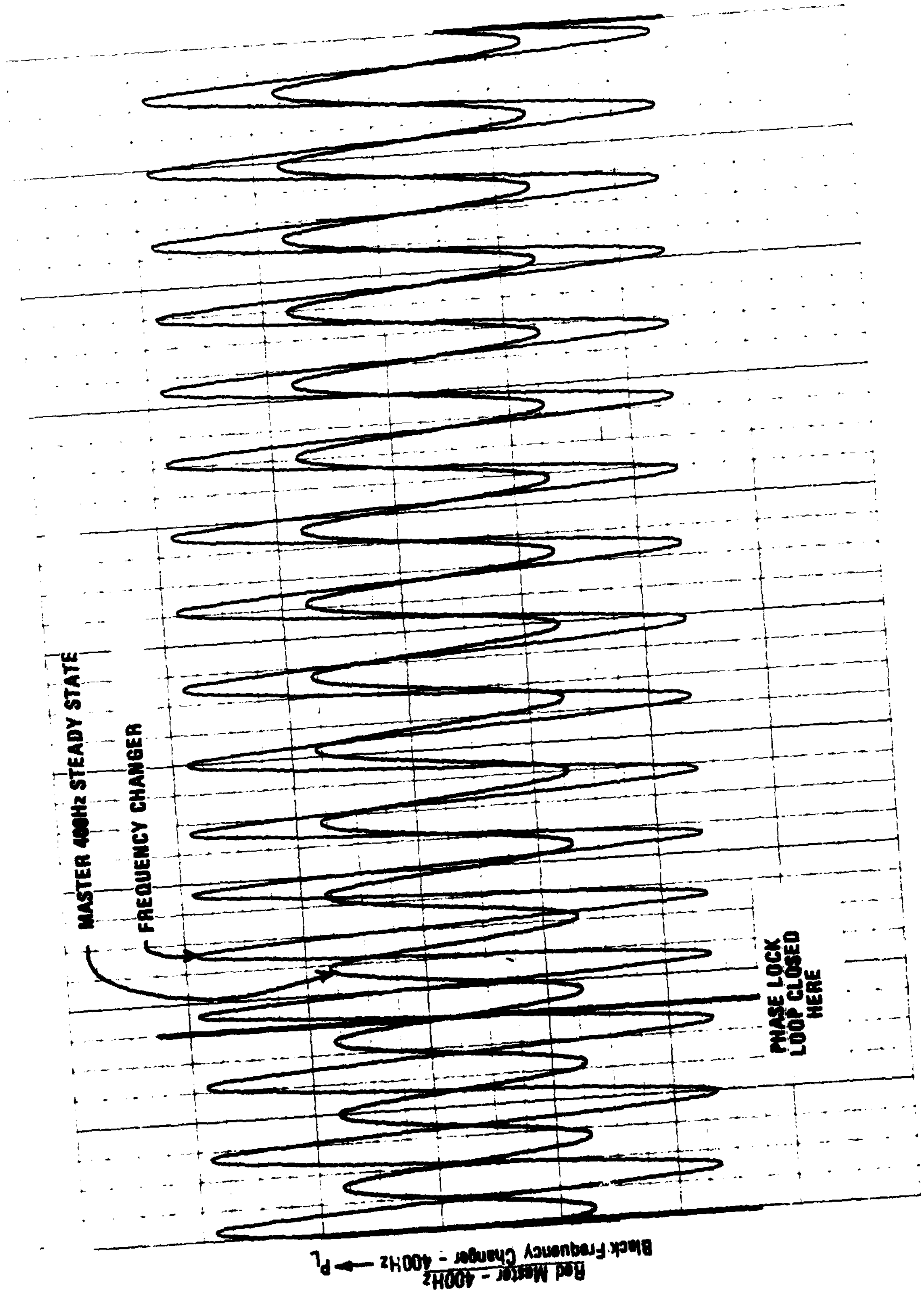
This test was run to show the capture characteristics of the phase lock loop. A Master three phase generator was operated at a constant 370 Hz. Prior to closing the Phase Lock switch, the frequency changer operated at 400 Hz on local (crystal) frequency control. The switch was then closed and the frequency changer was made to capture the Master 370 Hz in frequency and phase.

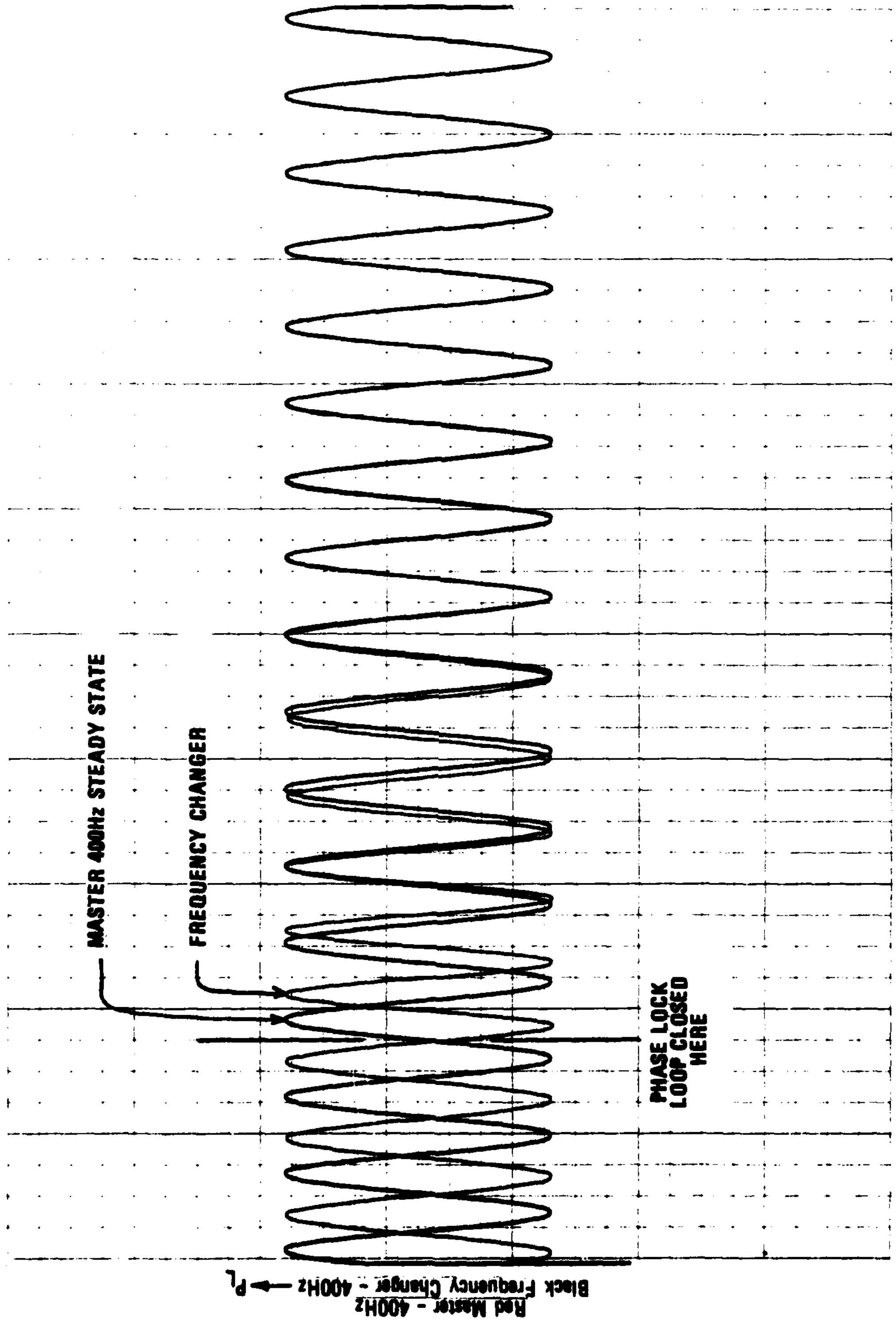
For the first test, at the time of closure the Master and the frequency changer were instantaneously nearly in phase. Frequency change and phase lock were accomplished smoothly in approximately three cycles. For the second test, at the time of closure, the Master and the frequency changer were instantaneously nearly 180 degrees out of phase. Again, frequency change and phase lock was accomplished smoothly. Full lock occurred in approximately ten cycles.

Test conditions for the third and fourth tests were like those of the second test except that the Master three-phase generator was replaced with a 10 kW Firefinder Generator Set (MEP D423A) operated at 400 Hz. The phase lock was in both cases accomplished smoothly. Full lock occurred in approximately eight cycles.


MASTER 370Hz STEADY STATE
SLAVE FREQUENCY CHANGER
PHASE LOCK LOOP CLOSED HERE
400Hz
Master - 370Hz
Frequency Changer - 400Hz


MASTER 370Hz STEADY STATE
SLAVE FREQUENCY CHANGER
PHASE LOCK
LOOP CLOSED
HERE
Master - 370Hz
Frequency Changer - 400Hz


MASTER 400Hz STEADY STATE
FREQUENCY CHANGER
PHASE LOCK LOOP CLOSED HERE
Black Frequency Changer - 400Hz → P_L
Red Master - 400Hz


MASTER 400Hz STEADY STATE
FREQUENCY CHANGER
PHASE LOCK LOOP CLOSED HERE
Black Frequency Changer - 400Hz ⟶ P_L
Red Master - 400Hz

EFFECT OF FREQUENCY TRANSIENTS ON PHASE LOCK

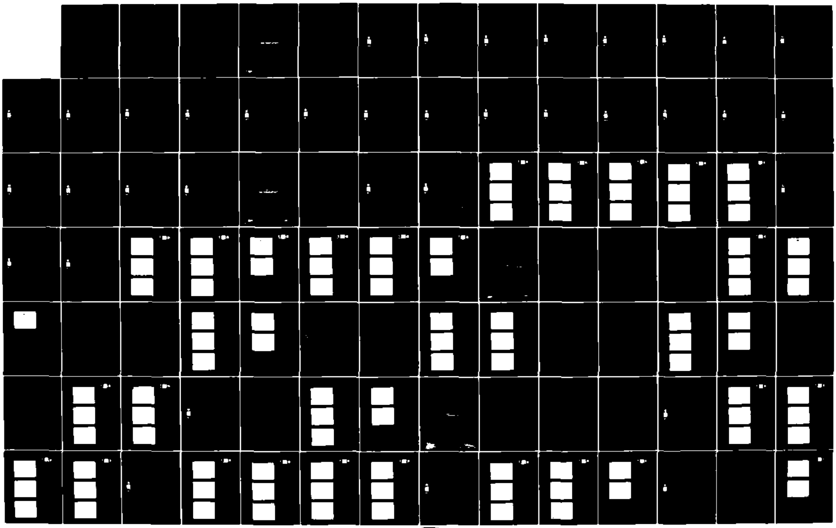
The paralleling controller phase lock circuit was tested to determine its response to a step change in frequency. For this testing the 15 kW Frequency Changer amplitude was operated on local control (Amplitude Lock was off). A three-phase oscillator, whose output frequency could be changed almost instantaneously relative to the 400 Hz nominal output, was used as a frequency reference for the Master inputs.

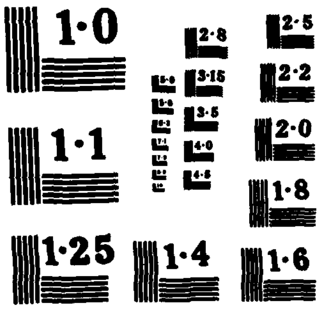
In the first test, the Master reference frequency was changed in a step fashion from 360 Hz to 440 Hz. In the second test, the Master reference frequency was changed in a step fashion from 440 Hz to 360 Hz. At 360 Hz, steady state, the frequency changer is seen to slightly lead the Master in phase. At 440 Hz, steady state, the frequency changer is seen to slightly lag the Master in phase. This steady state error is due primarily to the finite gain of the phase error loop in the paralleling controller. It is felt that this is an acceptable error.

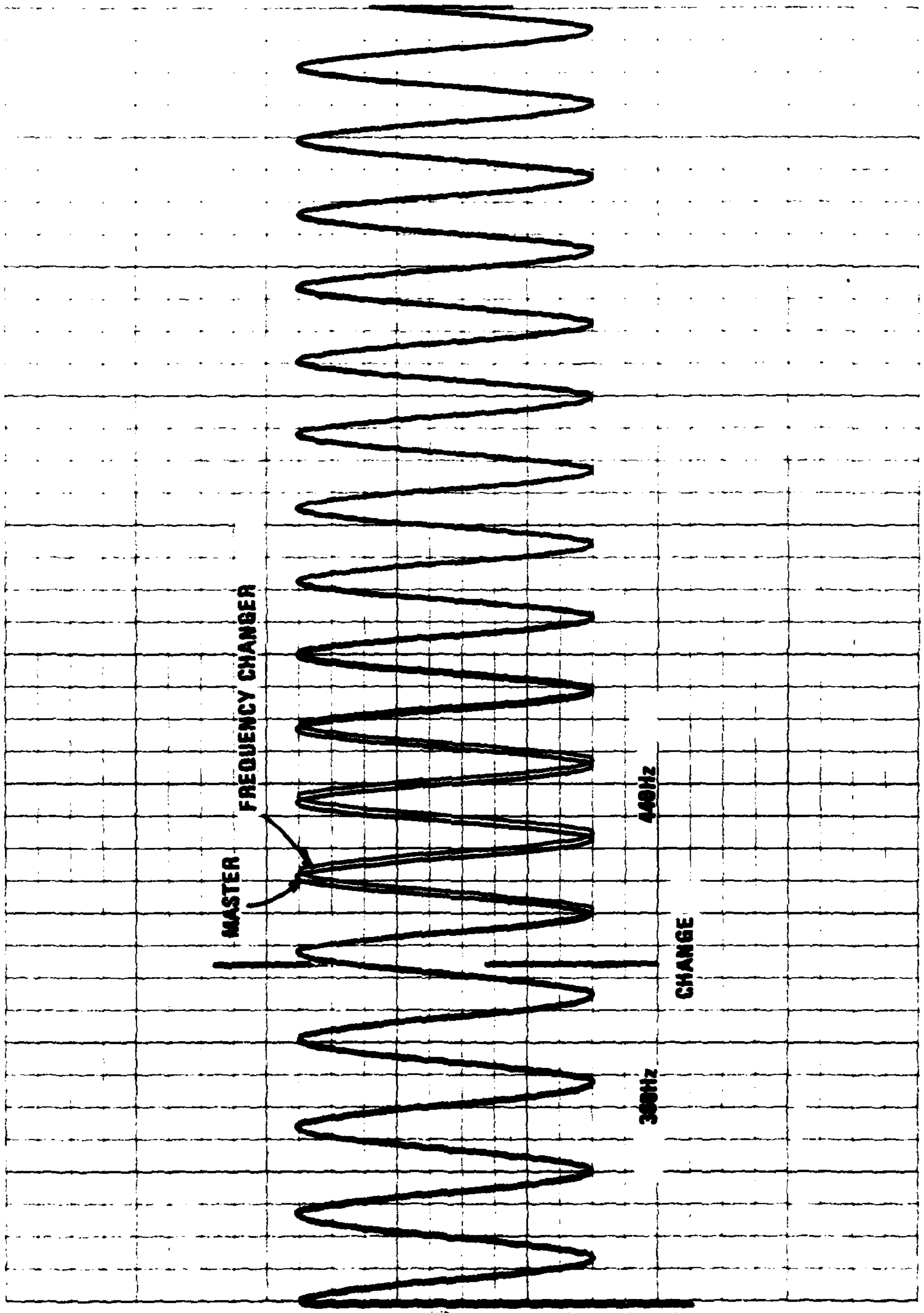
It should be noted that for a step change the recovery period is approximately five cycles with a somewhat overdamped characteristic. There is no apparent overshoot. This response is felt to be acceptable.

AD A145 531 PROGRESS IN POWER DISTRIBUTION IN FISCAL YEAR 1982(U) 2/4
GENERAL MOTORS CORP GOLETA CA DELCO ELECTRONICS DIV
OCT 82 R82-127

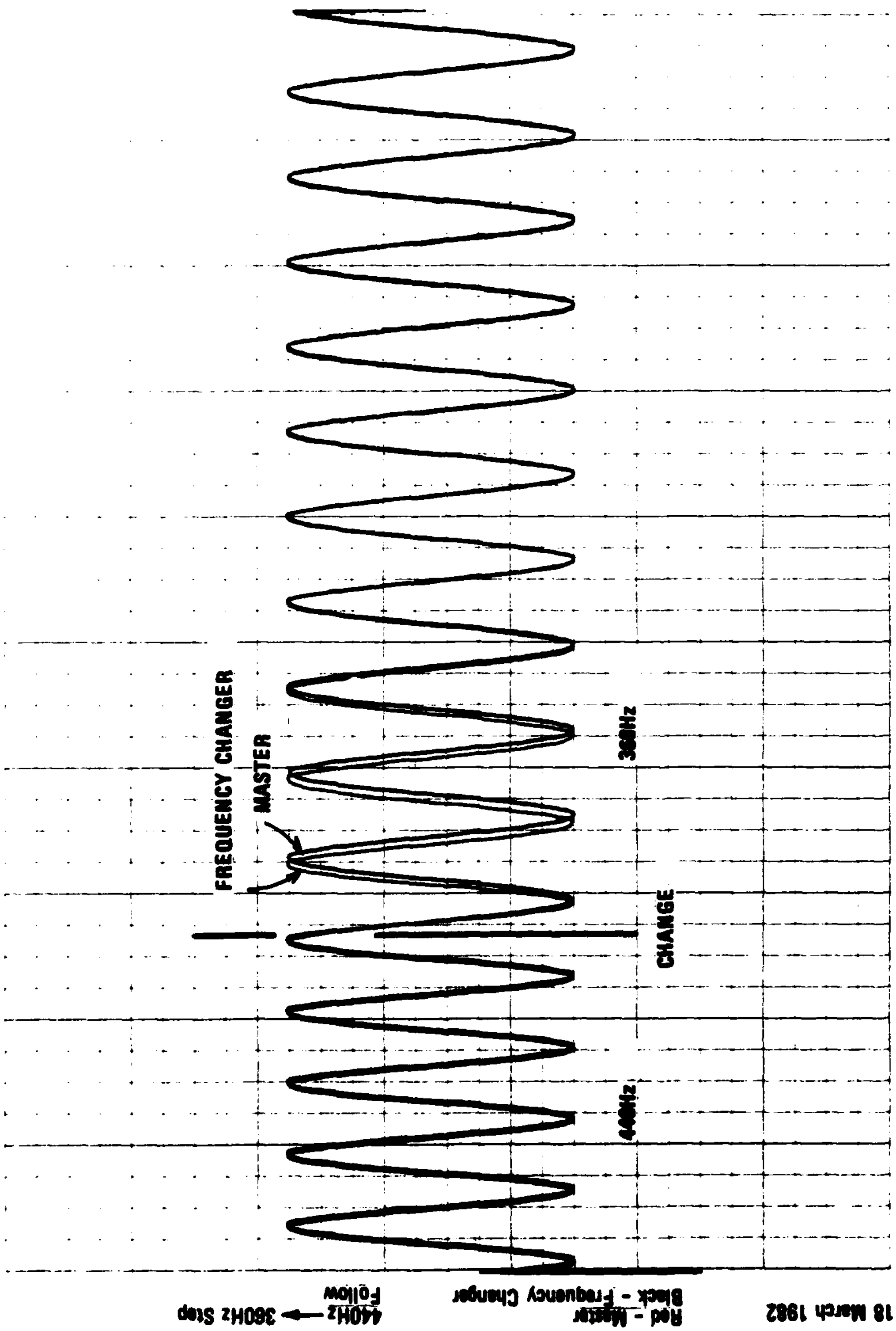
UNCLASSIFIED F/G 10/2 NL




1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5
2·8
3·15
3·5
4·0
4·5



18 March 1982 Red - Master
Black - Frequency Changer
360Hz → 440Hz Step
Follow



FREQUENCY CHANGER
MASTER
360Hz
CHANGE
440Hz
18 March 1982
Red - Master
Black - Frequency Changer
440Hz → 360Hz Step
Follow

15 kW FREQUENCY CHANGER INPUT CURRENT WAVEFORM TESTING WITH ORIGINAL INPUT FILTER

The 15 kW Frequency Changer, with the original single R-L-C input filter, was operated over a wide load range. The input current waveforms, THD, and harmonic components were recorded. Figure G-1 is a plot of some of the raw data, which appears in the following test records 01-03-01 through 01-03-08. Data were taken over the input current range of 10 to approximately 55 ARMS. This corresponds to a load range of approximately 10 to 110 percent from the converter portion (NL to 1.1 RL for the inverter portion).

Delco Electronics / GM

SANTA BARBARA, CALIFORNIA

EQUIP 15KW FREQ CHGR

MFGR DELCO

MODEL NO.

SERIAL NO.

REF:

TEST NO. SEE TEST REC

DATE MARCH 01, 1982

BY

TEST REC 01-03-01

THROUGH 01-03-08

ORIGINAL

INPUT FILTER

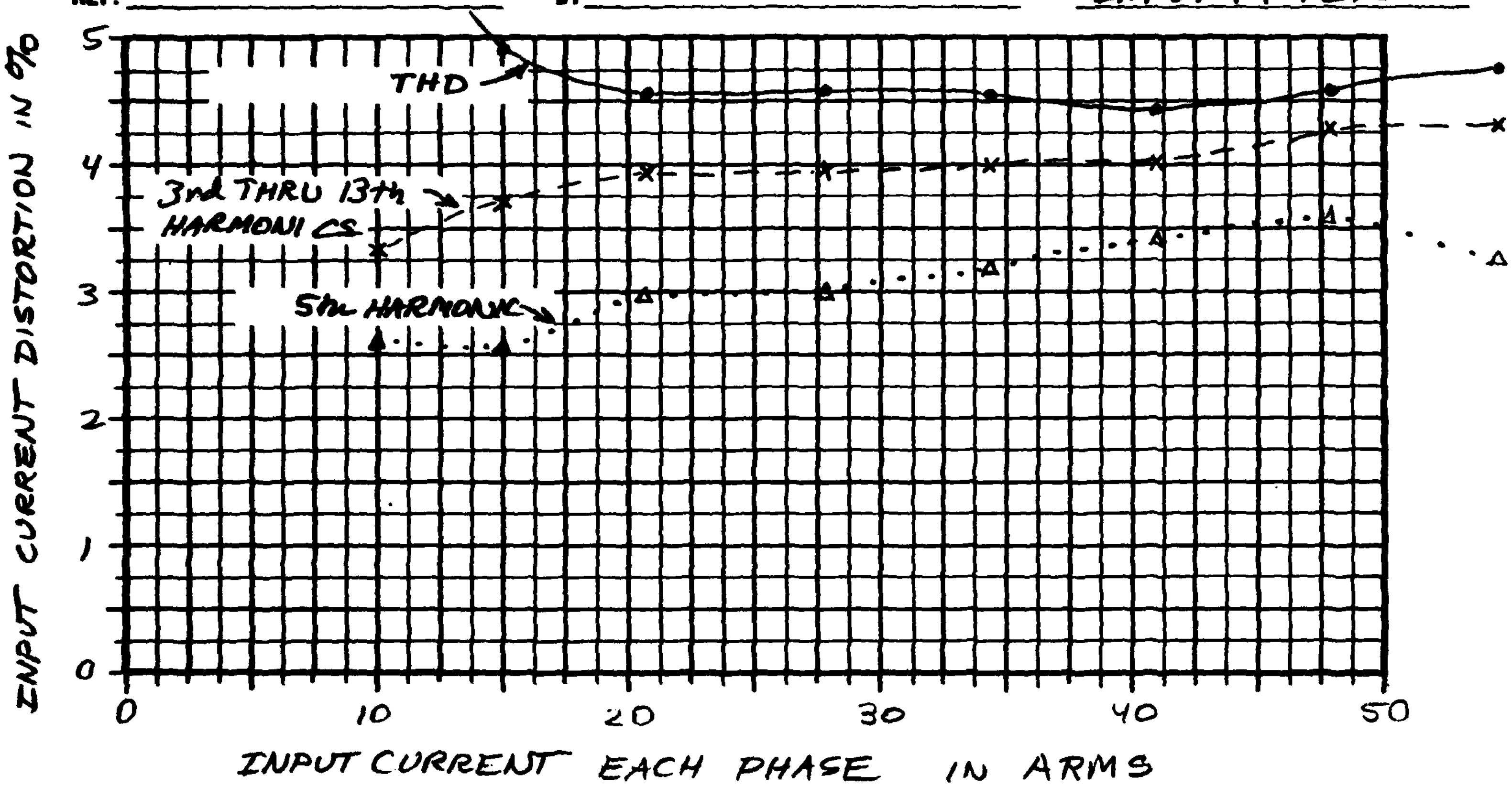


Figure G-1.

SSP9

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT , V-I-PWR

400Hz OUT

REF: POUT ≈ 15.5KW 0.8PF

TEST NO. 01-03-1

SHEET OF

DATE 1-MAR-82

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT φA VOLTAGE		118.9		V				
(b)	φA CURRENT		53.90		A				
(c)	φA PHASE ANGLE				deg				
(d)	φA POWER		6392		W				
(e)	φB VOLTAGE		119.8		V				
(f)	φB CURRENT		55.32		A				
(g)	φB PHASE ANGLE				deg				
(h)	φB POWER		6593		W				
(i)	φC VOLTAGE		119.0		V				
(j)	φC CURRENT		53.64		A				
(k)	φC PHASE ANGLE				deg				
(l)	φC POWER		6339		W				
(m)	CONV FREQUENCY				Hz				
(n)			19340						
(o)									

NOTES: LOAD BANK 1 SW 1,2,4,7 full LOAD BANK 2 SW 5,6,7 partial

ORIGINAL FILTER CONFIGURATION, NO EXTERNAL COMPONENTS

SSP3

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

Delco Electronics GM

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION HARMONIC ANALYSIS

INPUT CURRENT

REF:

TEST NO. 01-03-1

SHEET OF

DATE 1-MAR-82

PROJ ENGR

TEST BY

OBSERVER

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL Hz		100%	—
3rd		0.70 %	%
5th		3.25 %	%
7th		2.75 %	%
9th		0.20 %	%
11th		0.95 %	%
13th		— %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES:

4.36%

Delco Electronics GM
SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT CURRENT WAVEFORM

REF:

TEST NO. 01-03-1

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT CURRENT ϕA THD		4.42		4.42 %				
(b)	ϕB THD		4.62		4.62 %				
(c)	ϕC THD		4.75		4.75 %				
(d)	ϕA WV ANALYSIS								
(e)	ϕB WV ANALYSIS								
(f)	ϕC WV ANALYSIS								
(g)	ϕA DEV FACTOR				%				
(h)	ϕB DEV FACTOR				%				
(i)	ϕC DEV FACTOR				%				
(j)	ϕA VMOD POS				V				
(k)	ϕA VMOD NEG				V				
(l)	ϕB VMOD POS				V				
(m)	ϕB VMOD NEG				V				
(n)	ϕC VMOD POS				V				
(o)	ϕC VMOD NEG				V				

NOTES:

SSP5

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ____

MFGR ____

MODEL NO. ____

SERIAL NO. ____

TEST DESCRIPTION INPUT VOLTAGE WAVEFORM

REF: ____

TEST NO. 01-03-1

SHEET ____ OF ____

DATE 1-MAR-82

PROJ ENGR ____

TEST BY ____

OBSERVER ____

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ϕA THD		3.81		3.81 %				
(b)	ϕB THD		3.88		3.88 %				
(c)	ϕC THD		4.00		4.00 %				
(d)	ϕA WV ANALYSIS								
(e)	ϕB WV ANALYSIS								
(f)	ϕC WV ANALYSIS								
(g)	VOLTAGE ϕA DEV FACTOR				%				
(h)	ϕB DEV FACTOR				%				
(i)	ϕC DEV FACTOR				%				
(j)	ϕA VMOD POS				V				
(k)	ϕA VMOD NEG				V				
(l)	ϕB VMOD POS				V				
(m)	ϕB VMOD NEG				V				
(n)	ϕC VMOD POS				V				
(o)	ϕC VMOD NEG				V				

NOTES: ____

P4

Delco Electronics GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT , V-I-PWR

REF: ≃13.3KW 0.8PF

TEST NO. 01-03-2

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ΦA VOLTAGE		119.3		V				
(b)	ΦA CURRENT		47.22		A				
(c)	ΦA PHASE ANGLE				deg				
(d)	ΦA POWER		5605		W				
(e)	ΦB VOLTAGE		119.9		V				
(f)	ΦB CURRENT		48.39		A				
(g)	ΦB PHASE ANGLE				deg				
(h)	ΦB POWER		5753		W				
(i)	ΦC VOLTAGE		118.7		V				
(j)	ΦC CURRENT		46.76		A				
(k)	ΦC PHASE ANGLE				deg				
(l)	ΦC POWER		5508		W				
(m)	CONV FREQUENCY				Hz				
(n)			16870						
(o)									

NOTES:

46.76/5364 = 0.872

SSP3

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION HARMONIC ANALYSIS

INPUT CURRENT

REF:

TEST NO. 01-03-2

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL Hz		100%	——
3rd		0.50 %	%
5th		3.60 %	%
7th		2.20 %	%
9th		0.25 %	%
11th		0.55 %	%
13th		0.20 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES:

4.26"/5

Delco Electronics

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ____________

MFGR ____________

MODEL NO. ____________

SERIAL NO. ____________

TEST DESCRIPTION INPUT CURRENT WAVEFORM

REF: ____________

TEST NO. 01-03-2

SHEET ______ OF ______

DATE ____________

PROJ ENGR ____________

TEST BY ____________

OBSERVER ____________

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT CURRENT φA THD		4.85	0.872	4.23 %				
(b)	φB THD		5.05	0.872	4.40 %				
(c)	φC THD		5.25	0.872	4.58 %				
(d)	φA WV ANALYSIS								
(e)	φB WV ANALYSIS								
(f)	φC WV ANALYSIS								
(g)	φA DEV FACTOR				%				
(h)	φB DEV FACTOR				%				
(i)	φC DEV FACTOR				%				
(j)	φA VMOD POS				V				
(k)	φA VMOD NEG				V				
(l)	φB VMOD POS				V				
(m)	φB VMOD NEG				V				
(n)	φC VMOD POS				V				
(o)	φC VMOD NEG				V				

NOTES: ____________

SSP5

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT , ' -I-PWR

REF: 11.1KW 0.8PF

TEST NO. 01-03-3

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ΦA VOLTAGE		119.7		V				
(b)	ΦA CURRENT		40.31		A				
(c)	ΦA PHASE ANGLE				deg				
(d)	ΦA POWER		4795		W				
(e)	ΦB VOLTAGE		119.9		V				
(f)	ΦB CURRENT		41.25		A				
(g)	ΦB PHASE ANGLE				deg				
(h)	ΦB POWER		4897		W				
(i)	ΦC VOLTAGE		119.1		V				
(j)	ΦC CURRENT		39.80		A				
(k)	ΦC PHASE ANGLE				deg				
(l)	ΦC POWER		~~39.80~~	4682	W				
(m)	CONV FREQUENCY				Hz				
(n)			14380						
(o)									

NOTES:

39.80/ 53.64 = 0.742

SP3

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ______

MFGR ______

MODEL NO. ______

SERIAL NO. ______

TEST DESCRIPTION HARMONIC ANALYSIS

INPUT CURRENT ØC

REF: ______

TEST NO. 01-03-3

SHEET ______ OF ______

DATE ______

PROJ ENGR ______

TEST BY ______

OBSERVER ______

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL Hz		100%	——
3rd		0.40 %	%
5th		3.40 %	%
7th		2.00 %	%
9th		0.20 %	%
11th		0.60 %	%
13th		0.45 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES:

4.02%

SSP8

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ______

MFGR ______

MODEL NO. ______

SERIAL NO. ______

TEST DESCRIPTION INPUT CURRENT WAVEFORM

REF: ______

TEST NO. 01-03-3

SHEET ______ OF ______

DATE ______

PROJ ENGR ______

TEST BY ______

OBSERVER ______

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT CURRENT ϕA THD		5.42	0.742	4.02 %				
(b)	ϕB THD		5.68	0.742	4.21 %				
(c)	ϕC THD		5.98	0.742	4.44 %				
(d)	ϕA WV ANALYSIS								
(e)	ϕB WV ANALYSIS								
(f)	ϕC WV ANALYSIS								
(g)	ϕA DEV FACTOR				%				
(h)	ϕB DEV FACTOR				%				
(i)	ϕC DEV FACTOR				%				
(j)	ϕA VMOD POS				V				
(k)	ϕA VMOD NEG				V				
(l)	ϕB VMOD POS				V				
(m)	ϕB VMOD NEG				V				
(n)	ϕC VMOD POS				V				
(o)	ϕC VMOD NEG				V				

NOTES: ______

Delco Electronics [redacted] GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT , V–I–PWR

REF:

TEST NO. 01-03 -4

SHEET ___ OF ___

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ϕA VOLTAGE		120.4		V				
(b)	ϕA CURRENT		33.82		A				
(c)	ϕA PHASE ANGLE				deg				
(d)	ϕA POWER		4023		W				
(e)	ϕB VOLTAGE		120.6		V				
(f)	ϕB CURRENT		34.67		A				
(g)	ϕB PHASE ANGLE				deg				
(h)	ϕB POWER		4110		W				
(i)	ϕC VOLTAGE		119.6		V				
(j)	ϕC CURRENT		33.33		A				
(k)	ϕC PHASE ANGLE				deg				
(l)	ϕC POWER		3919		W				
(m)	CONV FREQUENCY				Hz				
(n)			12060						
(o)									

NOTES:

33.33/53.64 = 0.621

SSP3

Delco Electronics

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ______

MFGR ______

MODEL NO. ______

SERIAL NO. ______

TEST DESCRIPTION HARMONIC ANALYSIS

INPUT CURRENT ϕC

REF: ______

TEST NO. 01-03-4

SHEET ______ OF ______

DATE ______

PROJ ENGR ______

TEST BY ______

OBSERVER ______

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL Hz		100%	—
3rd		0.25 %	%
5th		3.20 %	%
7th		2.20 %	%
9th		0.10 %	%
11th		0.80 %	%
13th		0.35 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES:

3.98%

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT CURRENT WAVEFORM

REF:

TEST NO. 01-03-4

SHEET ____ OF ____

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT CURRENT ϕA THD		0.621	6.65	4.13 %				
(b)	ϕB THD		0.621	6.90	4.28 %				
(c)	ϕC THD		0.621	7.30	4.54 %				
(d)	ϕA WV ANALYSIS								
(e)	ϕB WV ANALYSIS								
(f)	ϕC WV ANALYSIS								
(g)	ϕA DEV FACTOR				%				
(h)	ϕB DEV FACTOR				%				
(i)	ϕC DEV FACTOR				%				
(j)	ϕA VMOD POS				V				
(k)	ϕA VMOD NEG				V				
(l)	ϕB VMOD POS				V				
(m)	ϕB VMOD NEG				V				
(n)	ϕC VMOD POS				V				
(o)	ϕC VMOD NEG				V				

NOTES:

SSP5

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT , V–I–PWR

REF:

TEST NO. 01-03-5

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ΦA VOLTAGE		120.6		V				
(b)	ΦA CURRENT		27.54		A				
(c)	ΦA PHASE ANGLE				deg				
(d)	ΦA POWER		3250		W				
(e)	ΦB VOLTAGE		120.8		V				
(f)	ΦB CURRENT		28.25		A				
(g)	ΦB PHASE ANGLE				deg				
(h)	ΦB POWER		3319		W				
(i)	ΦC VOLTAGE		119.9		V				
(j)	ΦC CURRENT		27.07		A				
(k)	ΦC PHASE ANGLE				deg				
(l)	ΦC POWER		3146		W				
(m)	CONV FREQUENCY				Hz				
(n)			9720						
(o)									

NOTES:

27.07 / 53.64 = 0.505

SP3

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION HARMONIC ANALYSIS

INPUT CURRENT ØC

REF:

TEST NO. 01-03-5

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL Hz		100%	——
3rd		0.25 %	%
5th		3.00 %	%
7th		2.30 %	%
9th		0.20 %	%
11th		1.00 %	%
13th		0.30 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES:

3.92%

SSP8

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ____________

MFGR ____________

MODEL NO. ____________

SERIAL NO. ____________

TEST DESCRIPTION INPUT CURRENT WAVEFORM

REF: ____________

TEST NO. 01-03-5

SHEET ______ OF ______

DATE ____________

PROJ ENGR ____________

TEST BY ____________

OBSERVER ____________

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ϕA THD		8.12	0.505	4.10 %				
(b)	ϕB THD		8.62	0.505	4.35 %				
(c)	ϕC THD		9.08	0.505	4.58 %				
(d)	ϕA WV ANALYSIS								
(e)	ϕB WV ANALYSIS								
(f)	ϕC WV ANALYSIS								
(g)	CURRENT ϕA DEV FACTOR				%				
(h)	ϕB DEV FACTOR				%				
(i)	ϕC DEV FACTOR				%				
(j)	ϕA VMOD POS				V				
(k)	ϕA VMOD NEG				V				
(l)	ϕB VMOD POS				V				
(m)	ϕB VMOD NEG				V				
(n)	ϕC VMOD POS				V				
(o)	ϕC VMOD NEG				V				

NOTES: ____________

SSP5

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT , V–I–PWR

REF:

TEST NO. 01-03-6

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ϕA VOLTAGE		121.9		V				
(b)	ϕA CURRENT		20.94		A				
(c)	ϕA PHASE ANGLE				deg				
(d)	ϕA POWER		2440		W				
(e)	ϕB VOLTAGE		122.1		V				
(f)	ϕB CURRENT		21.58		A				
(g)	ϕB PHASE ANGLE				deg				
(h)	ϕB POWER		2488		W				
(i)	ϕC VOLTAGE		121.0		V				
(j)	ϕC CURRENT		20.54		A				
(k)	ϕC PHASE ANGLE				deg				
(l)	ϕC POWER		2346		W				
(m)	CONV FREQUENCY				Hz				
(n)			7280						
(o)									

NOTES:

20.54/53.64 = 0.383

SSP3

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION HARMONIC ANALYSIS

INPUT CURRENT ΦC

REF:

TEST NO. 01-03-6

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL Hz		100%	——
3rd		0.20 %	%
5th		2.95 %	%
7th		2.10 %	%
9th		0.20 %	%
11th		1.45 %	%
13th		0.30 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES:

3.91%

Delco Electronics GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT CURRENT WAVEFORM

REF:

TEST NO. 01-03-6

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT CURRENT φA THD		10.7	0.383	4.10 %				
(b)	φB THD		11.6	0.383	4.44 %				
(c)	φC THD		12.0	0.383	4.60 %				
(d)	φA WV ANALYSIS								
(e)	φB WV ANALYSIS								
(f)	φC WV ANALYSIS								
(g)	φA DEV FACTOR				%				
(h)	φB DEV FACTOR				%				
(i)	φC DEV FACTOR				%				
(j)	φA VMOD POS				V				
(k)	φA VMOD NEG				V				
(l)	φB VMOD POS				V				
(m)	φB VMOD NEG				V				
(n)	φC VMOD POS				V				
(o)	φC VMOD NEG				V				

NOTES:

SSP5

G-22

Delco Electronics

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ______

MFGR ______

MODEL NO. ______

SERIAL NO. ______

TEST DESCRIPTION INPUT , V–I–PWR

REF: ______

TEST NO. 01-03-7

SHEET ______ OF ______

DATE ______

PROJ ENGR ______

TEST BY ______

OBSERVER ______

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ΦA VOLTAGE		122.1		V				
(b)	ΦA CURRENT		14.90		A				
(c)	ΦA PHASE ANGLE				deg				
(d)	ΦA POWER		1643		W				
(e)	ΦB VOLTAGE		122.3		V				
(f)	ΦB CURRENT		15.54		A				
(g)	ΦB PHASE ANGLE				deg				
(h)	ΦB POWER		1680		W				
(i)	ΦC VOLTAGE		121.5		V				
(j)	ΦC CURRENT		14.63		A				
(k)	ΦC PHASE ANGLE				deg				
(l)	ΦC POWER		1556		W				
(m)	CONV FREQUENCY				Hz				
(n)			4890						
(o)									

NOTES:

$14.63/53.64 = 0.273$

R82-127

SP3

Delco Electronics

GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ______

MFGR ______

MODEL NO. ______

SERIAL NO. ______

TEST DESCRIPTION HARMONIC ANALYSIS

INPUT CURRENT ØC

REF: ______

TEST NO. 01-03-7

SHEET ______ OF ______

DATE 01-MAR-82

PROJ ENGR ______

TEST BY ______

OBSERVER ______

MEASUREMENT		INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS			PIX NO.	
FUNDAMENTAL	Hz		100%	——
	3rd		0.30 %	%
	5th		2.60 %	%
	7th		2.10 %	%
	9th	0.50	~~2.5~~ %	%
	11th		1.60 %	%
	13th		0.30 %	%
	15th		%	%
	17th		%	%
	19th		%	%
	21st		%	%
	23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES:

3.72%

SSP8

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ______

MFGR ______

MODEL NO. ______

SERIAL NO. ______

TEST DESCRIPTION INPUT CURRENT WAVEFORM

REF: ______

TEST NO. 01-03-7

SHEET ______ OF ______

DATE ______

PROJ ENGR ______

TEST BY ______

OBSERVER ______

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT CURRENT φA THD		16.3	0.273	4.45 %				
(b)	φB THD		16.9	0.273	4.61 %				
(c)	φC THD		18.0	0.273	4.91 %				
(d)	φA WV ANALYSIS								
(e)	φB WV ANALYSIS								
(f)	φC WV ANALYSIS								
(g)	φA DEV FACTOR				%				
(h)	φB DEV FACTOR				%				
(i)	φC DEV FACTOR				%				
(j)	φA VMOD POS				V				
(k)	φA VMOD NEG				V				
(l)	φB VMOD POS				V				
(m)	φB VMOD NEG				V				
(n)	φC VMOD POS				V				
(o)	φC VMOD NEG				V				

NOTES: ______

JSP5

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT , V–I–PWR

REF: NL

TEST NO. 01-03-8

SHEET OF

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ΦA VOLTAGE		122.6		V				
(b)	ΦA CURRENT		9.62		A				
(c)	ΦA PHASE ANGLE				deg				
(d)	ΦA POWER		847		W				
(e)	ΦB VOLTAGE		122.7		V				
(f)	ΦB CURRENT		10.23		A				
(g)	ΦB PHASE ANGLE				deg				
(h)	ΦB POWER		860		W				
(i)	ΦC VOLTAGE		121.7		V				
(j)	ΦC CURRENT		9.48		A				
(k)	ΦC PHASE ANGLE				deg				
(l)	ΦC POWER		767		W				
(m)	CONV FREQUENCY				Hz				
(n)			2480						
(o)									

NOTES:

9.48/53.64 = 0.177

SSP3

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ____________

MFGR ____________

MODEL NO. ____________

SERIAL NO. ____________

TEST DESCRIPTION HARMONIC ANALYSIS

INPUT CURRENT ØC

REF: NL

TEST NO. 01-03-8

SHEET ______ OF ______

DATE 01-MAR-82

PROJ ENGR ____________

TEST BY ____________

OBSERVER ____________

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
HARMONIC ANALYSIS		PIX NO.	
FUNDAMENTAL Hz		100%	—
3rd		— %	%
5th		2.65 %	%
7th		1.50 %	%
9th		0.35 %	%
11th		1.30 %	%
13th		0.35 %	%
15th		%	%
17th		%	%
19th		%	%
21st		%	%
23rd		%	%

MEASUREMENT	INST. NO.(s)	MEAS.	SPEC.
25th		%	%
27th		%	%
29th		%	%
31st		%	%
33rd		%	%
35th		%	%
37th		%	%
39th		%	%
41st		%	%
43rd		%	%
45th		%	%
47th		%	%
49th		%	%

NOTES:

3.33%

R82-127

Delco Electronics

GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ____________

MFGR ____________

MODEL NO. ____________

SERIAL NO. ____________

TEST DESCRIPTION INPUT CURRENT WAVEFORM

REF: NL

TEST NO. 01-03-8

SHEET ______ OF ______

DATE ____________

PROJ ENGR ____________

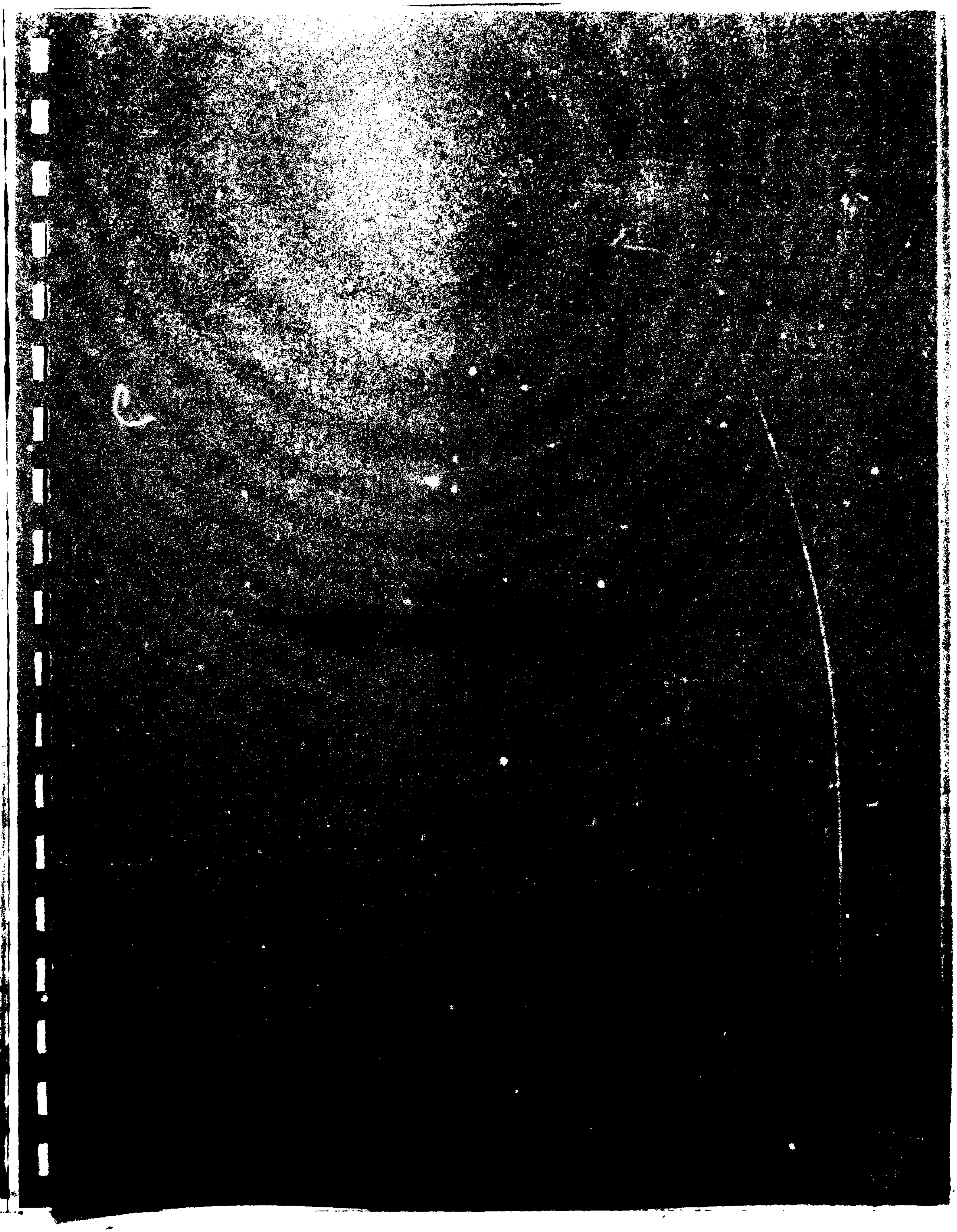
TEST BY ____________

OBSERVER ____________

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT CURRENT ϕA THD		32.0	0.177	5.66 %				
(b)	ϕB THD		32.5	0.177	5.75 %				
(c)	ϕC THD		34.5	0.177	6.10 %				
(d)	ϕA WV ANALYSIS								
(e)	ϕB WV ANALYSIS								
(f)	ϕC WV ANALYSIS								
(g)	ϕA DEV FACTOR				%				
(h)	ϕB DEV FACTOR				%				
(i)	ϕC DEV FACTOR				%				
(j)	ϕA VMOD POS				V				
(k)	ϕA VMOD NEG				V				
(l)	ϕB VMOD POS				V				
(m)	ϕB VMOD NEG				V				
(n)	ϕC VMOD POS				V				
(o)	ϕC VMOD NEG				V				

NOTES: ____________

SSP5



15 kW FREQUENCY CHANGER INPUT CURRENT WAVEFORM TESTING WITH AUGMENTED INPUT FILTER

The 15 kW Frequency Changer - with the original single R-L-C input filter augmented with a second R-L-C stage located externally to the frequency changer for lack of space internally - was operated over a wide load range. The input current waveforms, THD, and harmonic components were recorded.

Figure H-1 is a plot of some of the raw data which appears in test records 24-05-01 and 25-05-01. Data were taken over the input current range of 10 to approximately 55 Arms. This corresponds to a load range of approximately 10 to 110 percent for the converter portion (NL to 1.1 RL for the inverter portion).

EQUIP 15KW FREQ CHGR
MFGR DELCO
MODEL NO.
SERIAL NO.
REF:

Delco Electronics GM
SANTA BARBARA, CALIFORNIA

TEST NO. SEE TEST REC
DATE MAY 24 & 25 1982
BY

TEST REC 24-5-01
& 25-5-01

AUGMENTED
INPUT FILTER

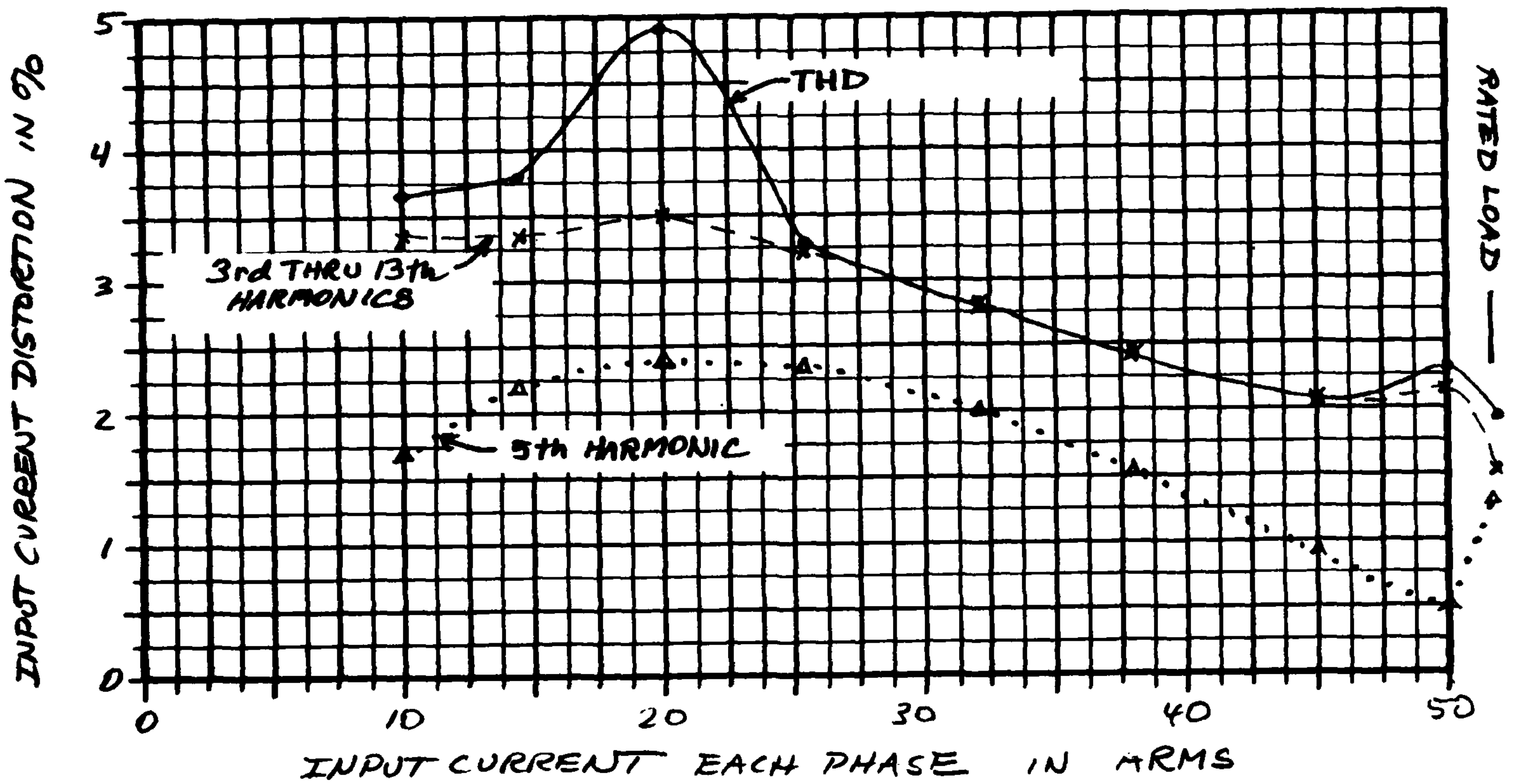


Figure H-1

R82-127

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 15KW
GENERAL PURPOSE
FREQUENCY CHANGER
MFGR DELCO
MODEL NO.
SERIAL NO.

TEST DESCRIPTION INPUT , V-I-PWR
CONVERTER INPUT
TESTS
REF: 17.3KW

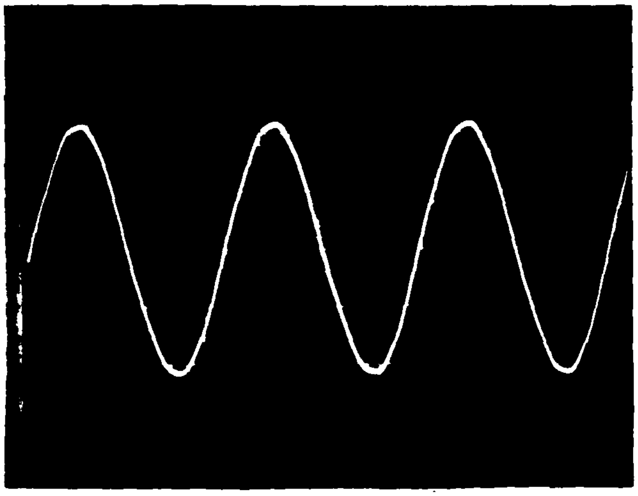
TEST NO. 2#-5-01
SHEET ___ OF ___
DATE 24-MAY-1982
PROJ ENGR
TEST BY C.K. Barrett
OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ϕA VOLTAGE		120.7		120.7 V				
(b)	ϕA CURRENT		52.25		52.25 A				
(c)	ϕA PHASE ANGLE		—		— deg	PF = 0.998			
(d)	ϕA POWER		6297		6297 W				
(e)	ϕB VOLTAGE		120.6		120.6 V				
(f)	ϕB CURRENT		53.32		53.32 A				
(g)	ϕB PHASE ANGLE		—		— deg	PF = 0.998			
(h)	ϕB POWER		6417		6417 W				
(i)	ϕC VOLTAGE		120.0		120.0 V				
(j)	ϕC CURRENT		52.54		52.54 A				
(k)	ϕC PHASE ANGLE		—		— deg	PF = 0.998			
(l)	ϕC POWER		6295		6295 W				
(m)	CONV FREQUENCY		—		— Hz				
(n)	TOTAL INPUT POWER		19009		19009 W				
(o)	TOTAL OUTPUT POWER		≈17300		≈17300 W				

NOTES: ABOVE READINGS TAKEN USING YEW 2505 / YEW 2514-47
DIGITAL WATTMETER
(c) PF = d/a×b
(g) PF = h/e×f
(k) PF = l/i×j

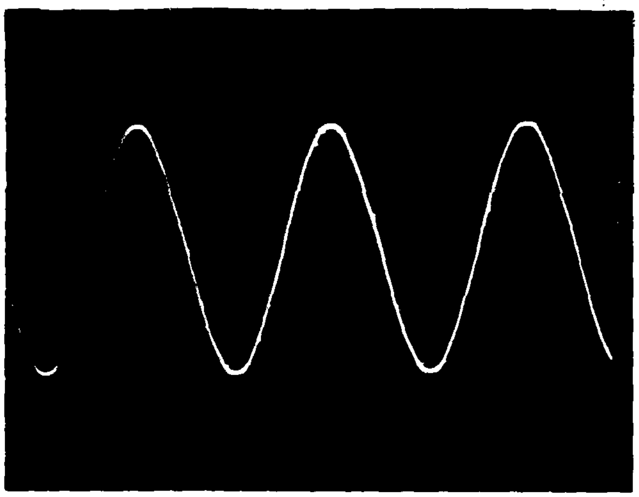
SSP3

SANTA BARBARA, CALIFORNIA

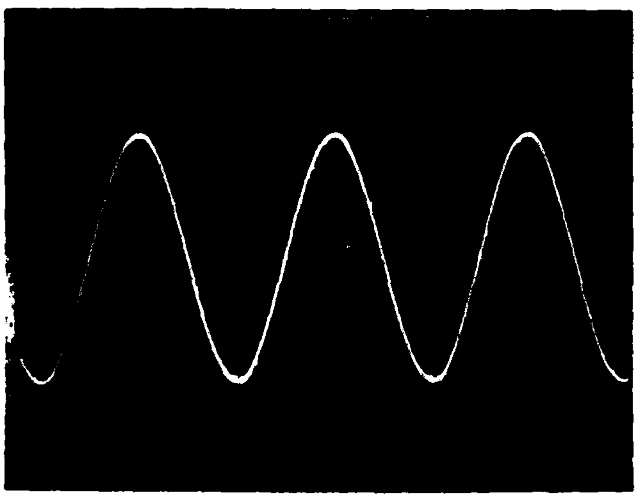


TEST DESCRIPTION L-N VOLTAGE WAVEFORMS

V1 VØA L-N (UNCAL)
V2 THD = 1.43%
V3 CONV NOT OPERATING
V4
H1
H2
TEST NO.
PIX NO.

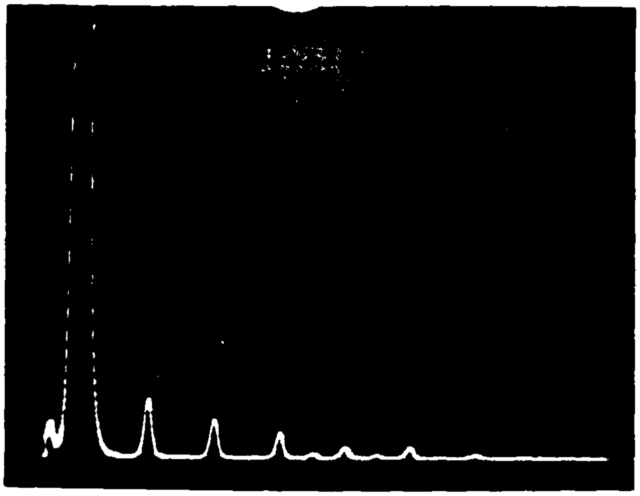


V1 VØB L-N
V2 THD = 1.46%
V3 CONV NOT OPERATING
V4
H1
H2
TEST NO.
PIX NO.



V1 VØC L-N
V2 THD = 0.78%
V3 CONV NOT OPERATING
V4
H1
H2
TEST NO.
PIX NO.

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION L-N VOLTAGE DISTORTION COMPONENTS

V1 VØA L-N (THD=1.43%)

V2 DISTORTION 1%/DIV

V3 CONV NOT

V4 OPERATING

H1 100 HZ/DIV

H2

TEST NO.

PIX NO.

V1 VØB (THD=1.46%)

V2

V3

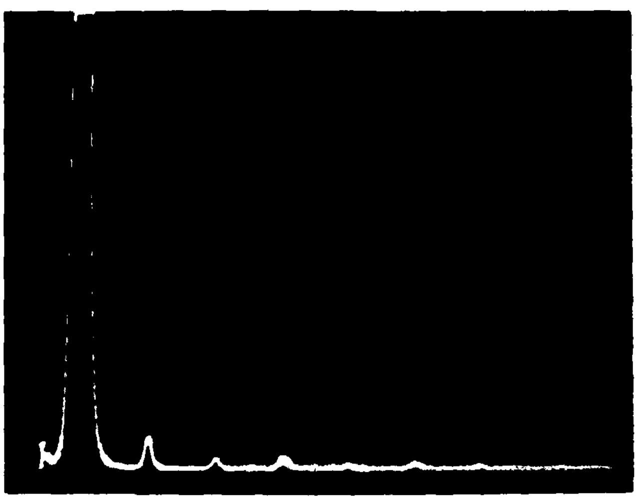
V4

H1

H2

TEST NO.

PIX NO.



V1 VØC (THD=0.78%)

V2

V3

V4

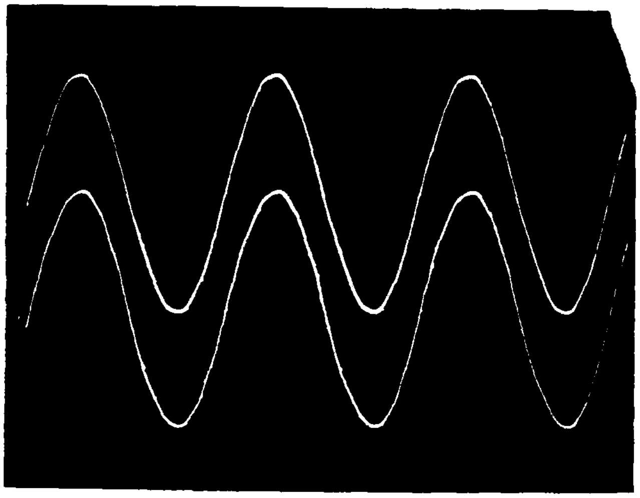
H1

H2

TEST NO.

PIX NO.

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION L-N VOLTAGE & CURRENT WAVEFORMS

V1 VØA L-N THD=1.22%

V2 IØA THD= 2.32%

V3 CONVERTER INPUT

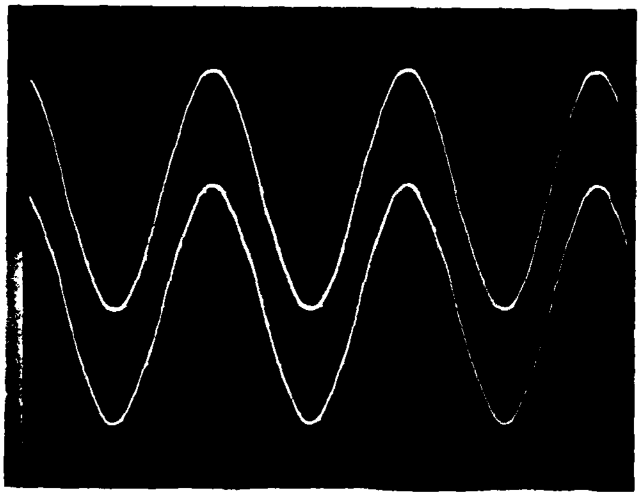
V4 POWER = 19 KW

H1

H2

TEST NO.

PIX NO. 1



V1 VØB L-N THD=1.50%

V2 IØB THD= 1.90%

V3

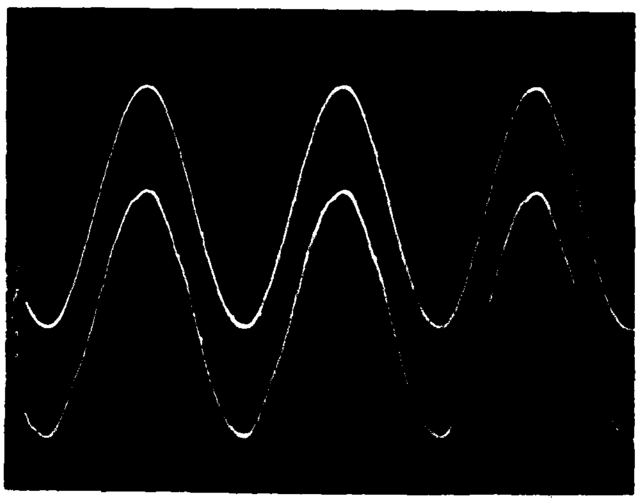
V4

H1

H2

TEST NO.

PIX NO. 2



V1 VØC L-N THD=0.85

V2 IØC THD=2.22%

V3

V4

H1

H2

TEST NO.

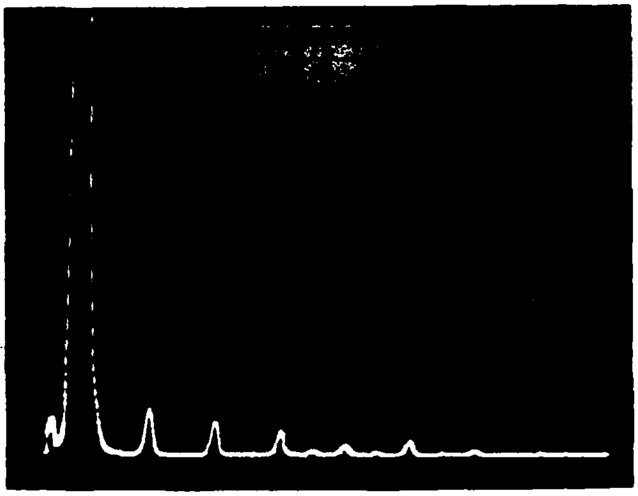
PIX NO. 3

R82-127

Delco Electronics

GM

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION L-N VOLTAGE DISTORTION COMPONENTS

V1 VØA L-N (THD=1.22%)

V2 DISTORTION 1%/DIV

V3 CONV INPUT 19KW

V4

H1 100Hz/DIV

H2

TEST NO.

PIX NO.

V1 VØB L-N (THD=1.50%)

V2

V3

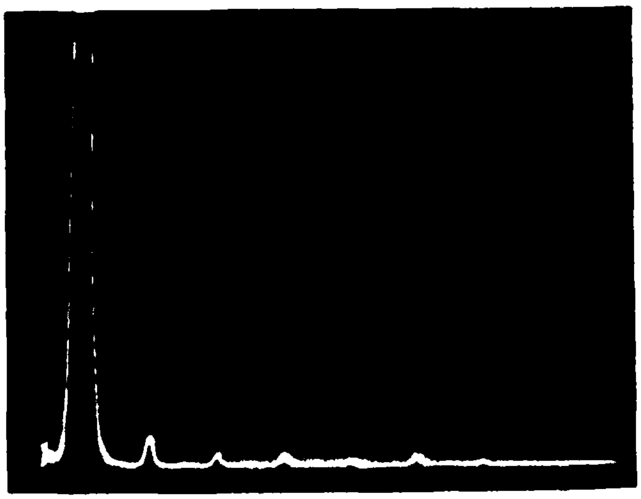
V4

H1

H2

TEST NO.

PIX NO.



V1 VØC L-N (THD=0.85%)

V2

V3

V4

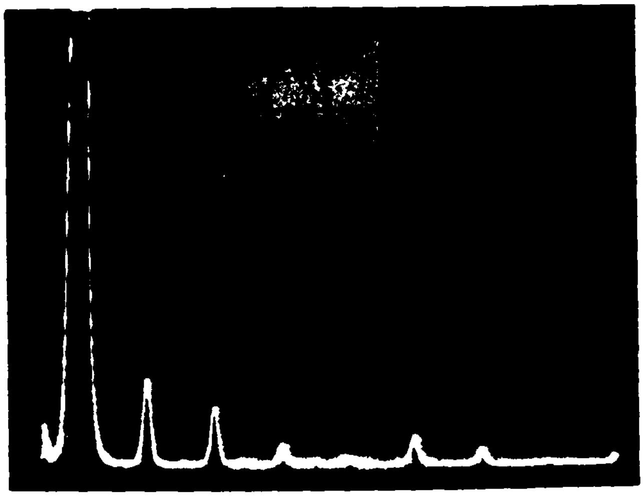
H1

H2

TEST NO.

PIX NO.

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION INPUT CURRENT DISTORTION COMPONENTS

V1 IφA (THD=2.32%)

V2 DISTORTION 1%/DIV

V3 CONV INPUT 19KW

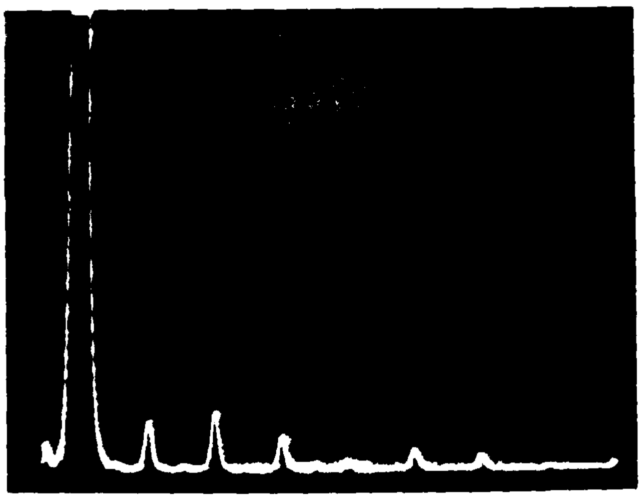
V4

H1 100HZ/DIV

H2

TEST NO.

PIX NO.



V1 IφB (THD=1.90%)

V2

V3

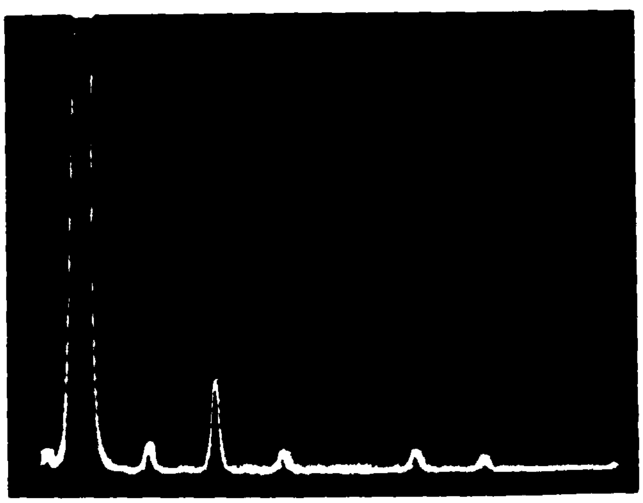
V4

H1

H2

TEST NO.

PIX NO.



V1 IφC (THD=2.22%)

V2

V3

V4

H1

H2

TEST NO.

PIX NO.

R82-127
SSP1

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 15KW
GENERAL PURPOSE
FREQ CHANGER
MFGR DELCO
MODEL NO.
SERIAL NO.

TEST DESCRIPTION INPUT , V-I-PWR
INPUT CURRENT
HARMONIC TESTS
REF:

TEST NO. 25-5-01
SHEET 1 OF 9
DATE 25 MAY 82
PROJ ENGR
TEST BY C. H. Barnett
OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ΦA VOLTAGE		120		V				
(b)	ΦA CURRENT		50.40	& down	A				
(c)	ΦA PHASE ANGLE				deg				
(d)	ΦA POWER				W				
(e)	ΦB VOLTAGE				V				
(f)	ΦB CURRENT				A				
(g)	ΦB PHASE ANGLE				deg				
(h)	ΦB POWER				W				
(i)	ΦC VOLTAGE				V				
(j)	ΦC CURRENT		50.46	& down	A				
(k)	ΦC PHASE ANGLE				deg				
(l)	ΦC POWER				W				
(m)	CONV FREQUENCY				Hz				
(n)	TOTAL POWER INPUT		≈ 18.1 KW	& down	To ≈	2 KW			
(o)									

NOTES: IΦA and IΦC examined at different power levels
LINE VOLTAGE DISTORTION W/O CONVERTER IS RATHER HIGH
AT THIS TIME ≈ 2% THD
ADD'L INPUT FILTER FOR THIS TEST SAME AS 26-02-01
L = 650 μH, R = 15Ω, C = 10μF (line To line)

SSP3

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION

REF:

TEST NO. 25-5-01

SHEET 2 OF 9

DATE

PROJ ENGR

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED THD	(4) CORR FACTOR	(5) MEASURED THD	(6) CALCULATIONS/OTHER WORST HARM. MEAS.	(7) PIX NO.	(8) PERF THD [illegible]	(9) SPEC
(a)	IØA 50.40 ARMS		2.30	50.40/50.40	2.30	1.95%, 3rd		[illegible]	
(b)	45.05 ARMS		2.35	45.05/a	2.10	1.55%, 3rd		[illegible]	
(c)	38.32 ARMS		3.20	38.32/a	2.43	1.55%, 5th		2.[illegible]	
(d)	32.03 ARMS		4.50	32.03/a	2.86	2.05%, 5th		2.[illegible]	
(e)	25.88 ARMS		6.40	25.88/a	3.29	2.35%, 5th		[illegible]	
(f)	19.92 ARMS		12.4	19.92/a	4.90	2.40%, 5th		3.49	
(g)	14.29 ARMS		13.4	14.29/a	3.80	2.20%, 7th		3.33	
(h)	10.10 ARMS		18.3	10.10/a	3.67	1.70%, 5th		[illegible]	
(i)									
(j)									
(k)									
(l)									
(m)									
(n)									
(o)									

NOTES:

SSP2

Delco Electronics | GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION

MFGR

MODEL NO.

SERIAL NO.

TEST DESCRIPTION

REF:

TEST NO. 25-5-01

SHEET 3 OF 9

DATE

PROJ ENGR

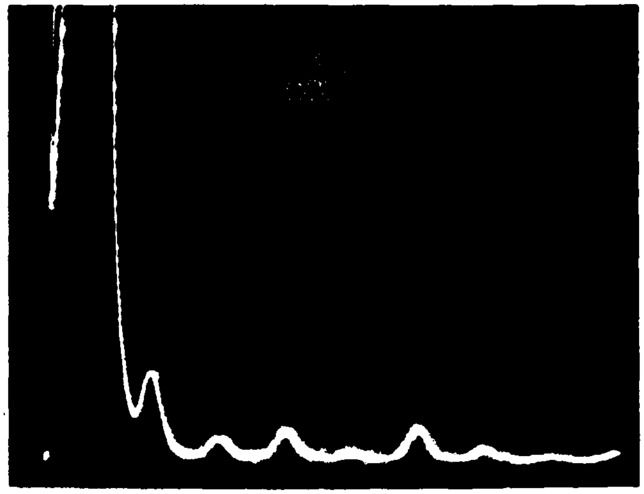
TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED THD	(4) CORR FACTOR	(5) MEASURED THD	(6) CALCULATIONS/OTHER WORST HARM. MEAS.	(7) PIX NO.	(8) PERE THD JS²	(9) SPEC LIMIT
(a)	Iφc 50.46 ARMS		1.32	50.46/a	1.32	0.80%, 3rd		1.26	[illegible]
(b)	45.30 ARMS		1.48	45.30/a	1.33	1.00%, 5th		1.34	
(c)	38.33 ARMS		2.42	38.33/a	1.84	1.55%, 5th		1.80	
(d)	32.03 ARMS		3.75	32.03/a	2.38	2.15%, 5th		2.39	
(e)	25.78 ARMS		5.90	25.78/a	3.01	2.60%, 5th		2.96	
(f)	19.80 ARMS		13.2	19.80/a	5.18	2.95%, 5th		3.43	
(g)	14.19 ARMS		14.5	14.19/a	4.08	*3.00%, 5th		3.48	3.00%
(h)	10.14 ARMS		20.5	10.14/a	4.12	2.65%, 5th		3.68	
(i)									
(j)									
(k)									
(l)									
(m)									
(n)									
(o)									

NOTES:

SSP2



Delco Electronics

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION ______

V1 IφA 50.40 ARMS

V2

V3 1%/DIV

V4

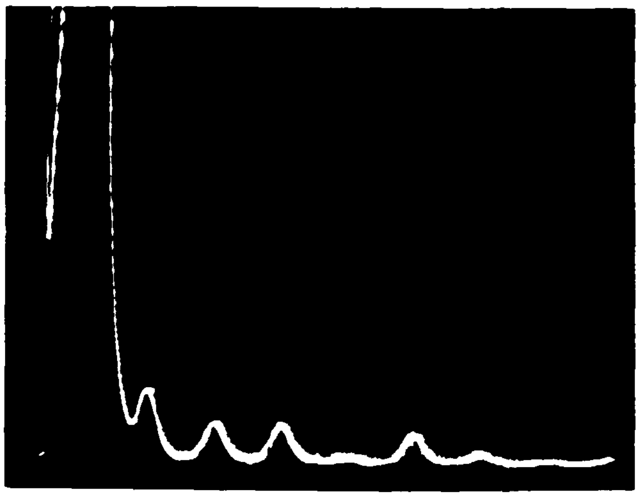
H1 100Hz/DIV

H2

TEST NO. 25-5-01

PIX NO.

THD = 2.19



V1 IφA 45.05 ARMS

V2 (ref 50.40)

V3 1%/DIV

V4

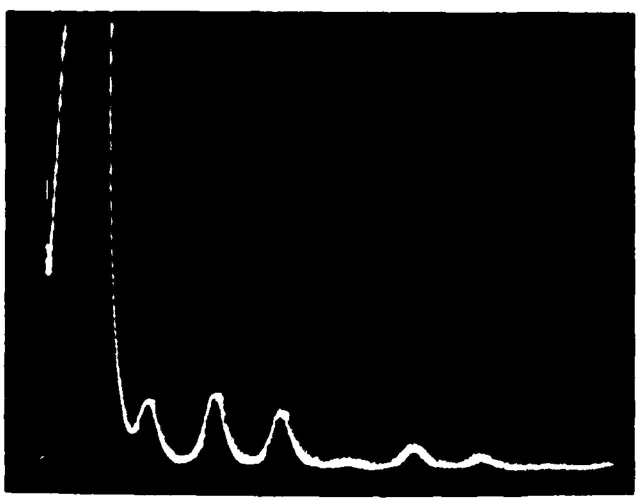
H1

H2

TEST NO.

PIX NO.

THD = 2.13



V1 IφA 38.32 ARMS

V2 (ref 50.40 FS)

V3 1%/DIV

V4

H1

H2

TEST NO.

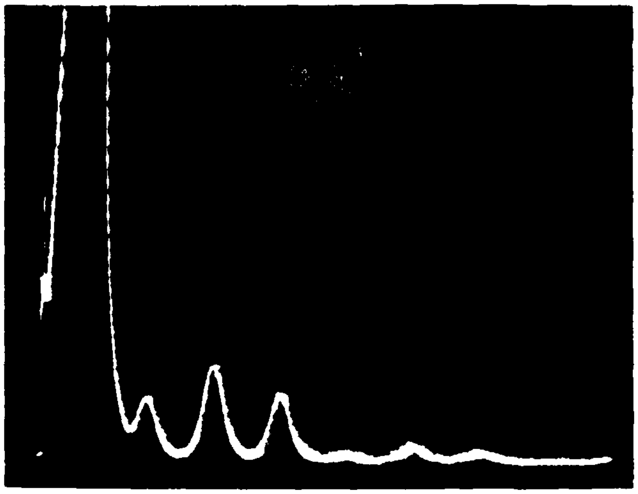
PIX NO.

THD = [illegible]

Delco Electronics

GM

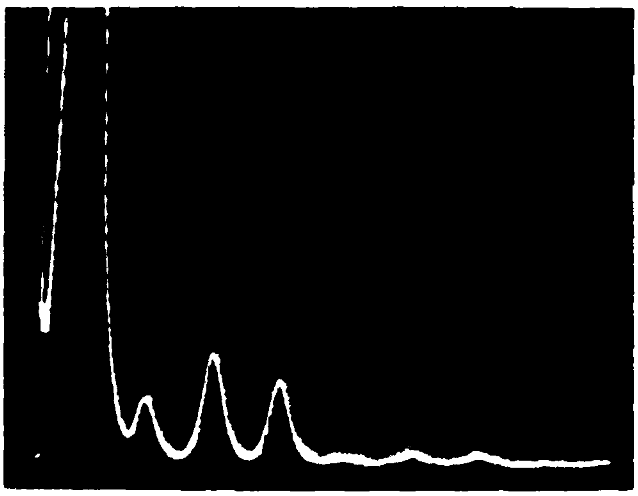
SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION

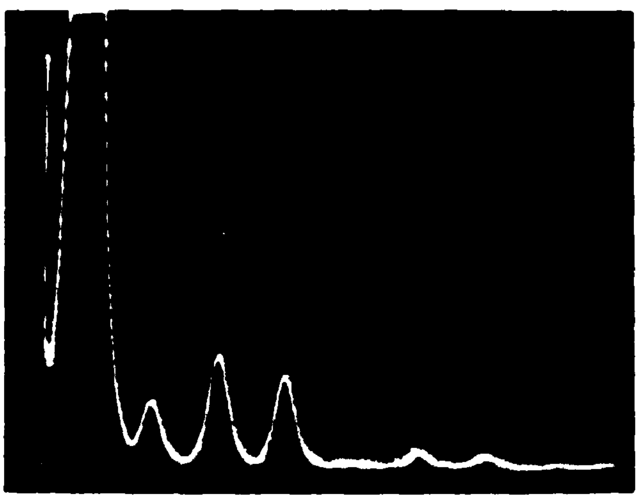
V1 IΦA 32.03 ARMS
V2 (ref 50.40A FS)
V3 1%/DIV
V4
H1 200 Hz/DIV
H2
TEST NO. 25-5-01
PIX NO.

THD = 2.87%



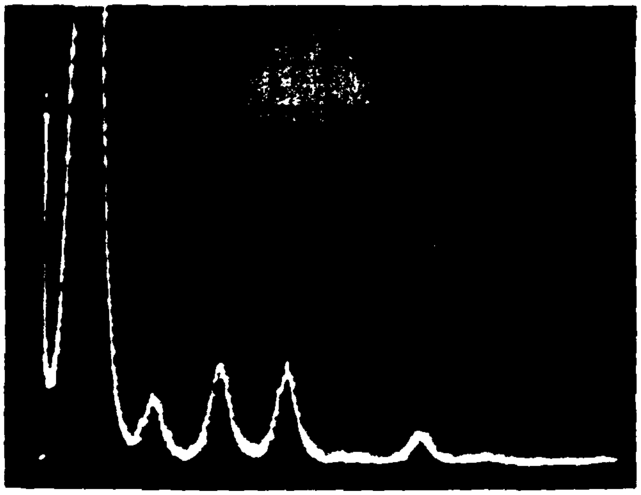
V1 IΦA 25.88 ARMS
V2 (ref 50.40A FS)
V3 1%/DIV
V4
H1
H2
TEST NO.
PIX NO.

THD = 2.[illegible]%



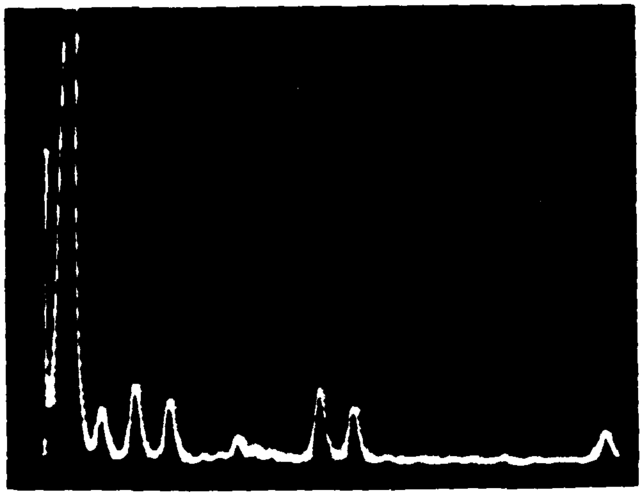
V1 IΦA 19.92 ARMS
V2 (ref 50.40A FS)
V3 1%/DIV
V4
H1
H2
TEST NO.
PIX NO.

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION ______

V1 IΦA 14.29 ARMS
V2 (ref 50.40 A FS)
V3 1%/DIV
V4
H1
H2
TEST NO. 25-5-01
PIX NO.
[illegible] 3.33



V1 IΦA 10.10 ARMS
V2 (ref 50.40 A FS)
V3 1%/DIV
V4
H1 200 Hz/DIV
H2
TEST NO.
PIX NO.
[illegible] 3.34

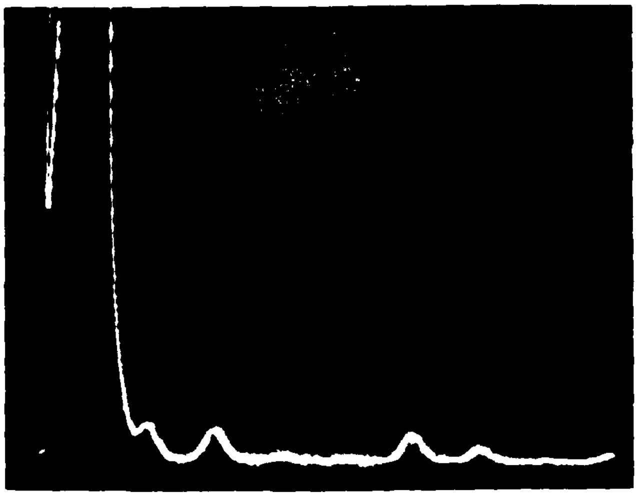
V1
V2
V3
V4
H1
H2
TEST NO.
PIX NO.

R82-127
SSP1

Delco Electronics

GM

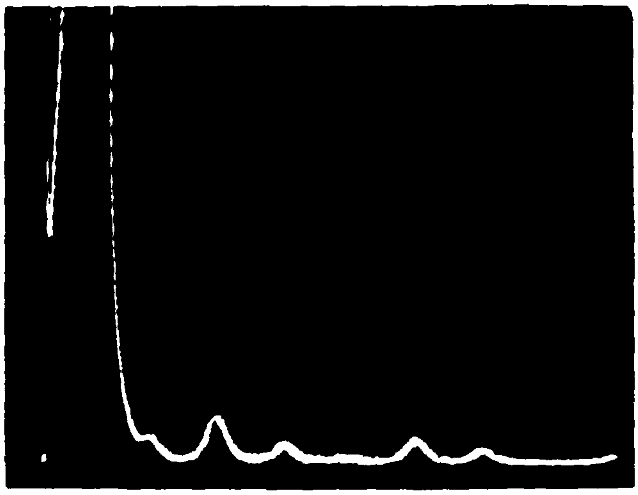
SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION

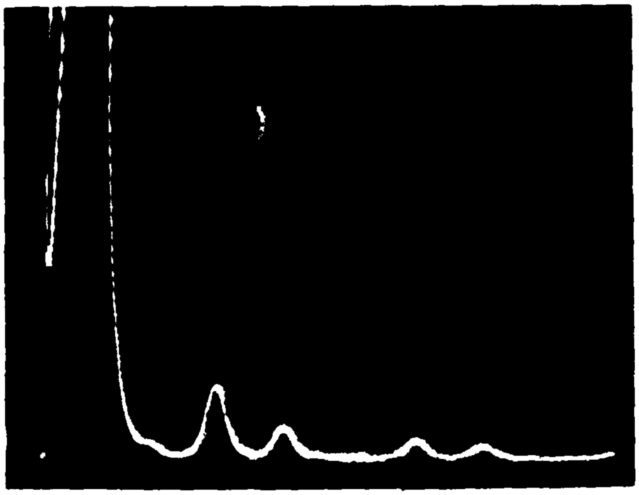
V1 IϕC 50.46 ARMS
V2 50.46A = FS
V3 1%/DIV
V4
H1 100HZ/DIV
H2
TEST NO. 25-5-01
PIX NO.

THD = 1.26



V1 IϕC 45.30 ARMS
V2 (ref 50.46A FS)
V3 1%/DIV
V4
H1
H2
TEST NO.
PIX NO.

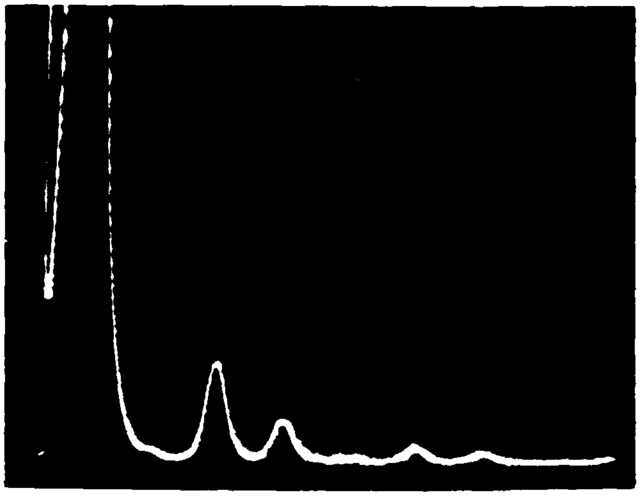
THD = 1.31



V1 IϕC 38.33 ARMS
V2 (ref 50.46 A FS)
V3 1%/DIV
V4
H1
H2
TEST NO.
PIX NO.

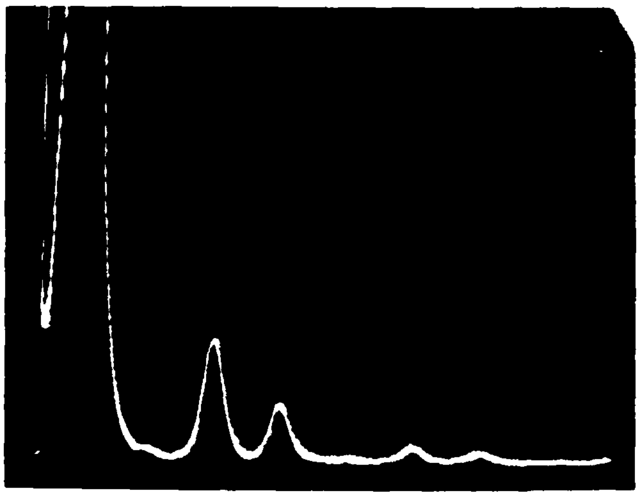
THD = 1.80

SANTA BARBARA, CALIFORNIA

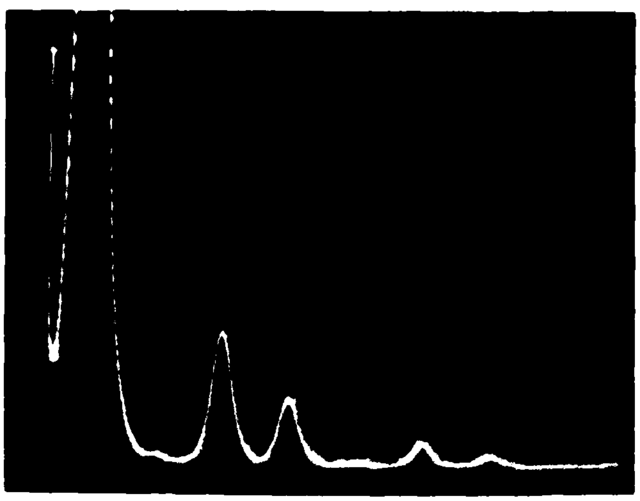


TEST DESCRIPTION ______________

V1 IØc 32.03 ARMS
V2 (ref 50.46A FS)
V3 1%/DIV
V4
H1 100Hz/DIV
H2
TEST NO. 25-5-01
PIX NO.
THD = 2.39



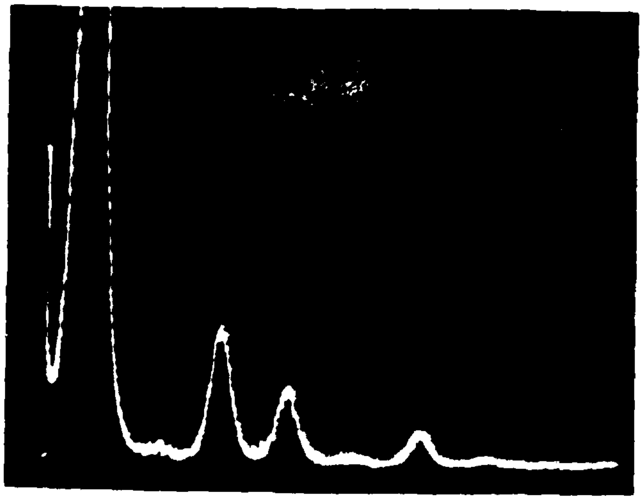
V1 IØc 25.78 ARMS
V2 (ref 50.46A FS)
V3 1%/DIV
V4
H1
H2
TEST NO.
PIX NO.
THD = 2.96



V1 IØc 19.80 ARMS
V2 (ref 50.46A FS)
V3 1%/DIV
V4
H1
H2
TEST NO.
PIX NO.
THD = 3.43

R82-127

SSP1

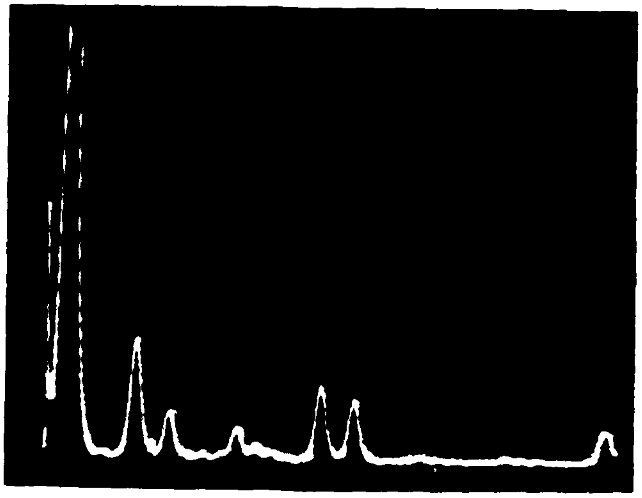


SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION ______

V1 Iφc 14.9 ARMS
V2 (ref. 50.46A FS)
V3 1%/DIV
V4
H1 100Hz/DIV
H2
TEST NO. 25-5-01
PIX NO.

THD = 3.48



V1 Iφc 10.14 ARMS
V2 (ref 50.46A FS)
V3 1%/DIV
V4
H1 200Hz/DIV
H2
TEST NO.
PIX NO.

V1
V2
V3
V4
H1
H2
TEST NO.
PIX NO.

INVERTER OUTPUT WAVEFORM DEGRADATION WITH NONLINEAR LOADING

The Delco inverter, similar to that used in the 15 kW Frequency Changer, was tested to determine the nature of the output waveform degradation which occur when specific nonlinear loads are applied. A part of this effort involved running comparative testing on a conventional motor driven alternator (MG) set.

A substitution was made for the 15 kW Frequency Changer, which at this writing, malfunctions with transient overloads - such as is characteristic of some of the nonlinear loads used in these tests. Substituted was the 10 kW Firefinder Generator Set, MEP D423A. The MG set used is a 12.5 kVA, 400 Hz MG set manufactured by Electric Machinery Manufacturing Company.

Loading for all tests was at the 10 kW level and was inherently equal on all the phases of the two units tested. In no case was there any component of normal linear nature; rather, total loading was nonlinear and produced by different rectifier circuits.

In test 17-06-01 the MG set was used to drive a three-phase, full wave rectifier bridge (not to be confused with three single full wave bridges) and a resistive load. For test 16-06-01, the Delco inverter was used with the same nonlinear load. There was little waveform degradation when the Delco inverter was used and the total harmonic distortion (THD) of its output was approximately 3 percent. The MG set produced approximately 12 percent THD.

In test 17-06-04, the MG set was used to drive the same rectifier bridge with small inductance, large capacitance filter ahead of the 10 kW resistive load. There was some waveform degradation in test 17-06-02, to approximately 5 percent THD when the Delco inverter was used with this (a very common type) of nonlinear load. The MG set produced about 12 percent THD with this load.

In test 17-06-05, the MG set was used to drive the same rectifier bridge with a large inductance (nearly critical), large capacitance filter ahead of the 10 kW resistive load. The Delco inverter, in test 17-06-03, displayed approximately 3.5 percent THD while the MG set displayed approximately 12 percent THD.

Delco Electronics GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 12.5KVA, 400HZ, 120/208V M-G Set

MFGR Electric Machinery Mfg. Co.

MODEL NO.

SERIAL NO. 1Q144072/3

TEST DESCRIPTION M-G SET OUTPUT WAVEFORM WITH NON-LINEAR LOADING

REF: 0KW

TEST NO. 17-06-01

SHEET 1 OF 5

DATE 17-JUN-82

PROJ ENGR A.H. BARRETT

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	VØA (TRUE RMS)	YEW 2505/	122.8		122.8 VRMS		1,4,5		
(b)	VØB	2514A	125.0		125.0 VRMS		2		
(c)	VØC		124.7		124.7 VRMS		3		
(d)	IØA		28.04		28.04 ARMS		1,6,7		
(e)	IØB		28.14		28.14 ARMS		2		
(f)	IØC		28.63		28.63 ARMS		3		
(g)	PØA		3247		3247 W	PF = 0.943			
(h)	PØB		3326		3326 W	PF = 0.962			
(i)	PØC		3385		3385 W	PF = 0.948			
(j)	PTOT		9960		9960 W				
(k)	VØA THD	HP 339A	12.2		12.2%		4,5		
(l)	VØB THD		9.6		9.6%				
(m)	VØC THD		9.2		9.2%				
(n)	IØA THD		22.2		22.2%		6,7		
(o)	IØB THD		23.6		23.6%				

NOTES: LOAD CONFIGURATION: 3Ø FULL WAVE BRIDGE WITH PURE RESISTIVE LOAD

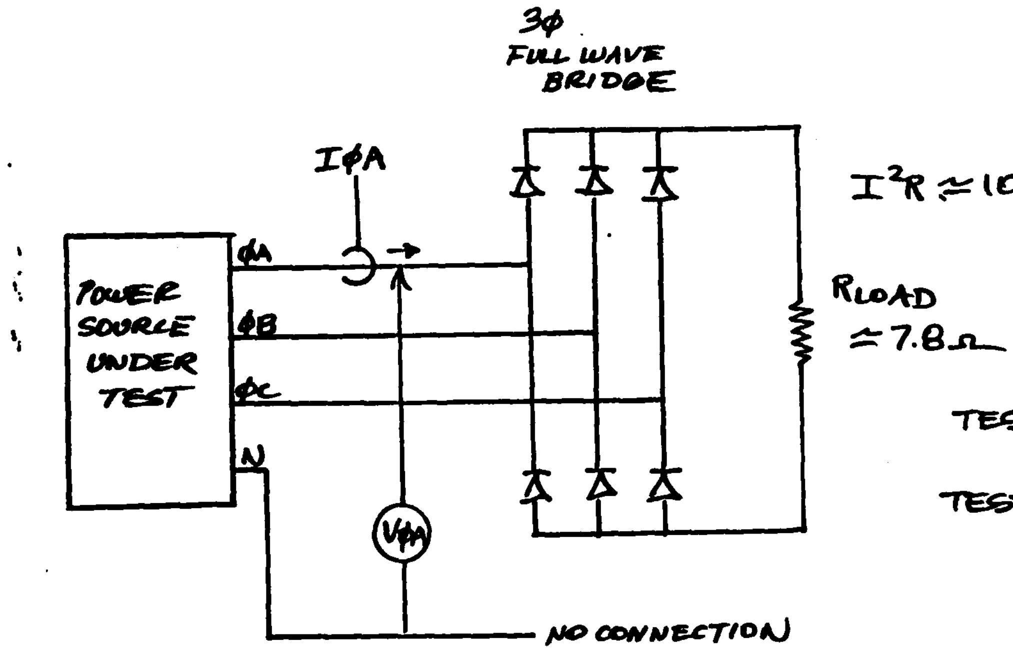
SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 12.5 KVA, 400 Hz, 120/208 V M-G SET
MFGR Electric Machinery Mfg. Co.
MODEL NO.
SERIAL NO. L6L44072/3

TEST DESCRIPTION M-G SET OUTPUT WAVEFORM WITH NON-LINEAR LOADING
REF:

TEST NO. 17-06-01
SHEET 2 OF 5
DATE 17-JUN-82
PROJ ENGR A.H. BARRETT
TEST BY
OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	IφC THD	HP 339A	21.8		81.8%				

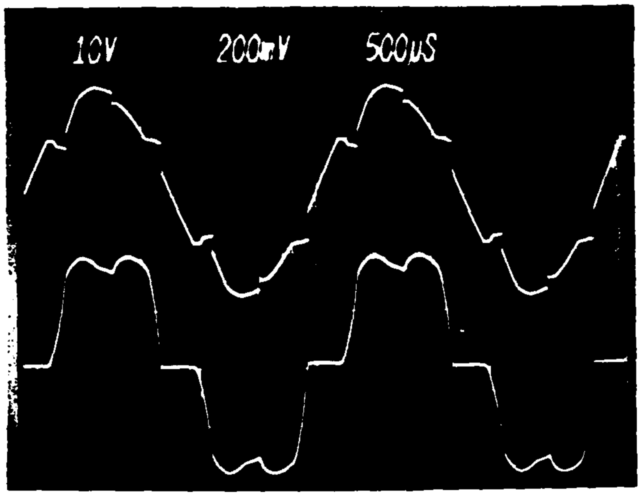


TEST CONFIGURATION FOR TESTS 16-06-01
17-06-01

Delco Electronics

GM

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION ______

V1 VφA 100V/DIV

V2 IφA 20A/DIV

V3

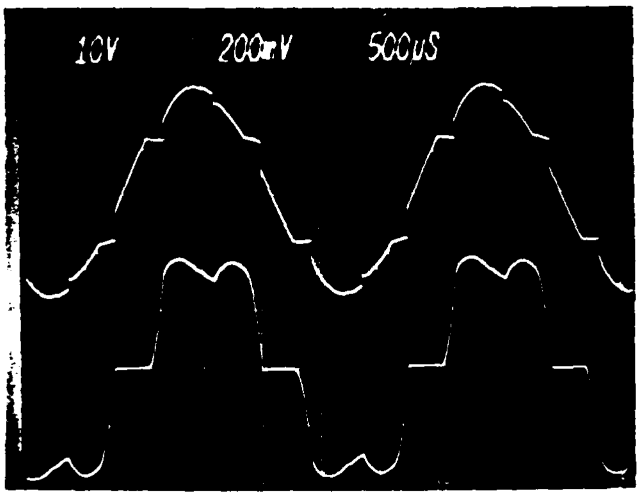
V4

H1 500μs /DIV

H2

TEST NO. 17-06-01

PIX NO. 1



V1 VφB 100V/DIV

V2 IφB 20A/DIV

V3

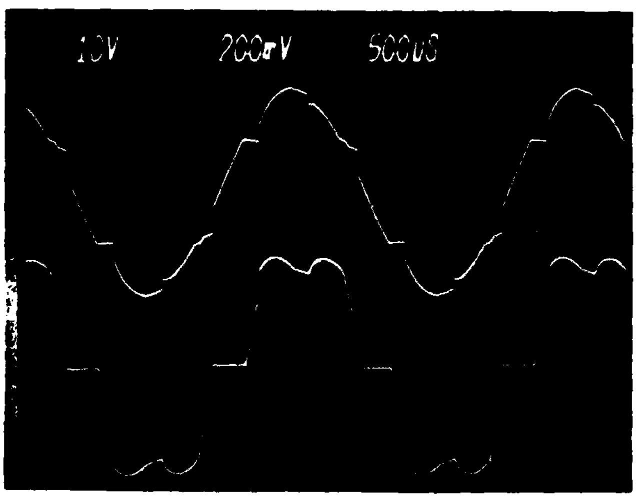
V4

H1 500μs /DIV

H2

TEST NO. 17-06-01

PIX NO. 2



V1 Vφc 100V/DIV

V2 Iφc 20A/DIV

V3

V4

H1 500μs /DIV

H2

TEST NO. 17-06-01

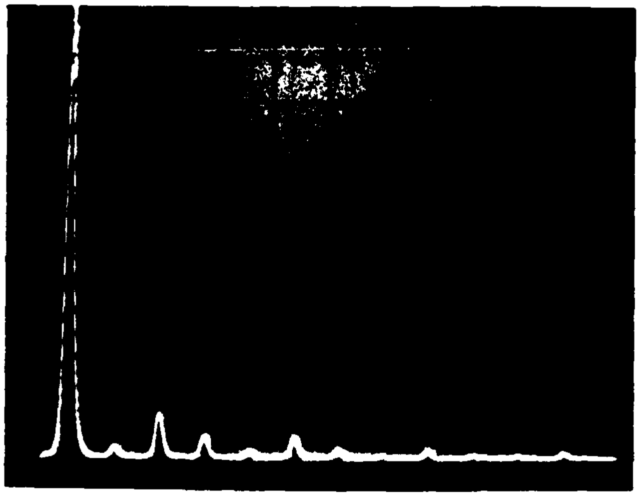
PIX NO. 3

Delco Electronics

GM

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION ______



V1 SPECTRUM VØA

V2 10%/DIV

V3

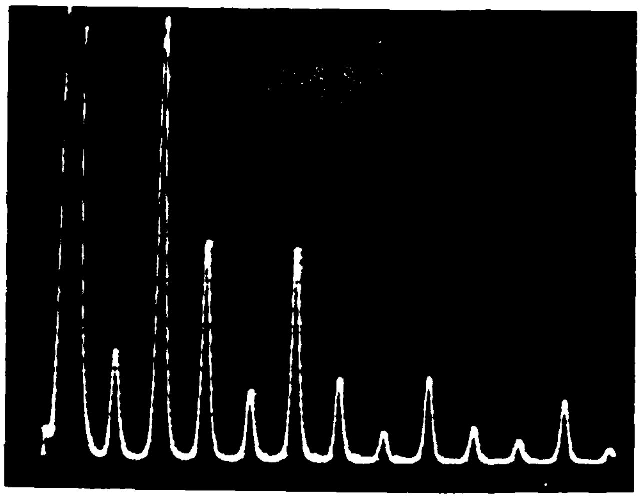
V4

H1 1KHz/DIV

H2

TEST NO. 17-06-01

PIX NO. 4



V1 SPECTRUM VØA

V2 10%/DIV

V3

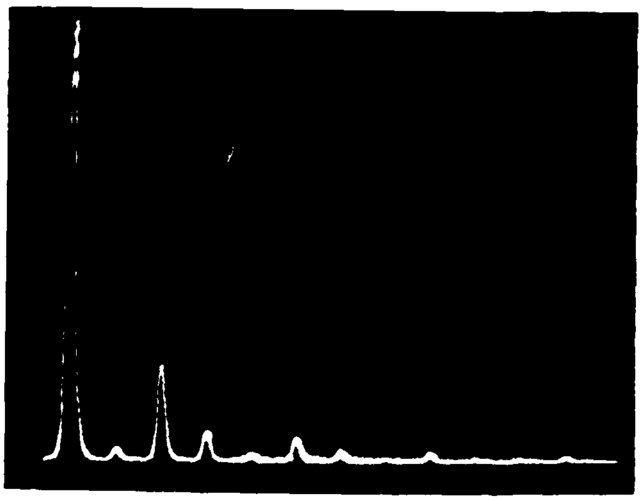
V4

H1 1KHz/DIV

H2

TEST NO. 17-06-01

PIX NO. 5



V1 SPECTRUM IØA

V2 10%/DIV

V3

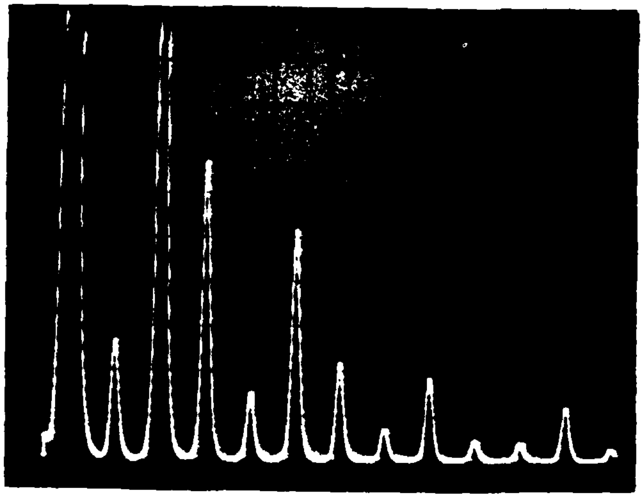
V4

H1 1KHz

H2

TEST NO. 17-06-01

PIX NO. 6



Delco Electronics

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION ____________

V1 SPECTRUM IØA
V2 1%/DIV
V3
V4
H1 1KHz
H2
TEST NO. 17-06-01
PIX NO. 7

V1
V2
V3
V4
H1
H2
TEST NO.
PIX NO.

V1
V2
V3
V4
H1
H2
TEST NO.
PIX NO.

Delco Electronics | GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 10KW FIREFINDER PCU/ TURBINE/ALT

MFGR DELCO

MODEL NO. TBU D423A

SERIAL NO. TEST BED UNIT 1

TEST DESCRIPTION INVERTER OUTPUT WAVEFORM WITH NON-LINEAR LOADING

REF: TKIU

TEST NO. 16-06-01

SHEET 1 OF 4

DATE 16-JUN-82

PROJ ENGR A.H. BARRETT

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	VØA TRUE RMS	YEW 2505	122.0		122.0 VRMS		1,4		
(b)	VØB	2514-47	121.9		121.9 VRMS		2		
(c)	VØC		121.9		121.9 VRMS		3		
(d)	IØA		28.83		28.83 ARMS		1,5		
(e)	IØB		28.83		28.83 ARMS		2		
(f)	IØC		28.82		28.82 ARMS		3		
(g)	PØA		3354		3354 W	PF=0.954			
(h)	PØB		3353		3353 W	PF=0.954			
(i)	PØC		3349		3349 W	PF=0.953			
(j)	PTOT		10060		10060 W				
(k)	VØA THD	HP 339A	2.98		2.98%		4		
(l)	VØB THD		2.91		2.91%				
(m)	VØC THD		2.91		2.91%				
(n)	IØA THD		27.4		27.4%		5		
(o)	IØB THD		27.6		27.6%				

NOTES: LOAD CONFIGURATION: 3Ø FULL WAVE BRIDGE WITH PURE RESISTIVE LOAD

Delco Electronics GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 10KW FIREFINDER PCU/ TURBINE/ALT

MFGR DELCO

MODEL NO. D423A

SERIAL NO. TEST BED UNIT 1

TEST DESCRIPTION INVERTER OUTPUT WAVEFORM WITH NON-LINEAR LOADING

REF:

TEST NO. 16-06-01

SHEET 2 OF 4

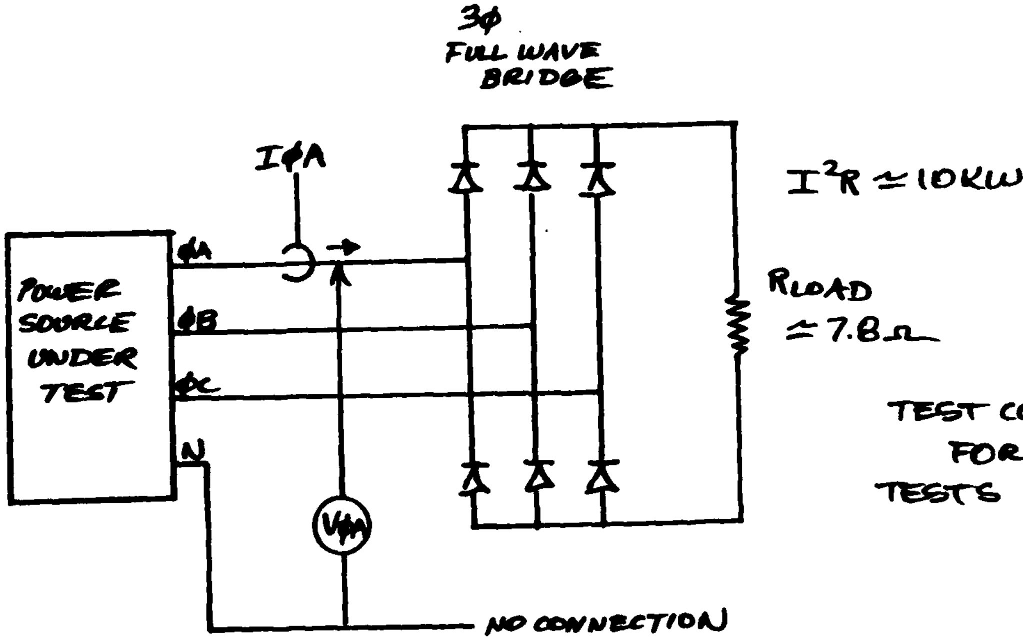
DATE 16-JUN-82

PROJ ENGR A.H. BARRETT

TEST BY

OBSERVER

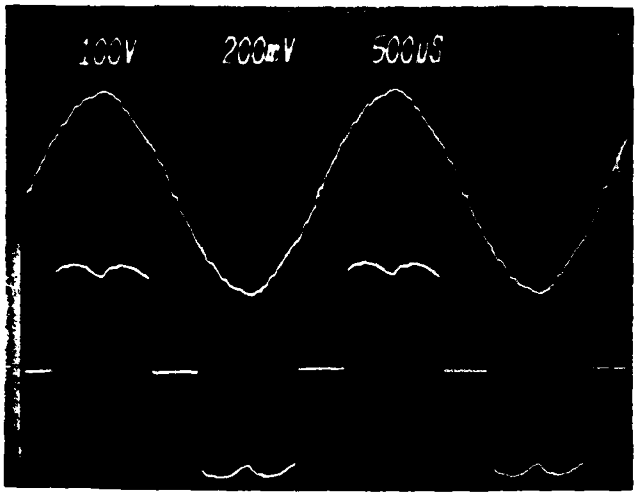
	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	IφC THD	HP 339A	27.5		27.5%				



TEST CONFIGURATION FOR TESTS 16-06-01 17-06-01

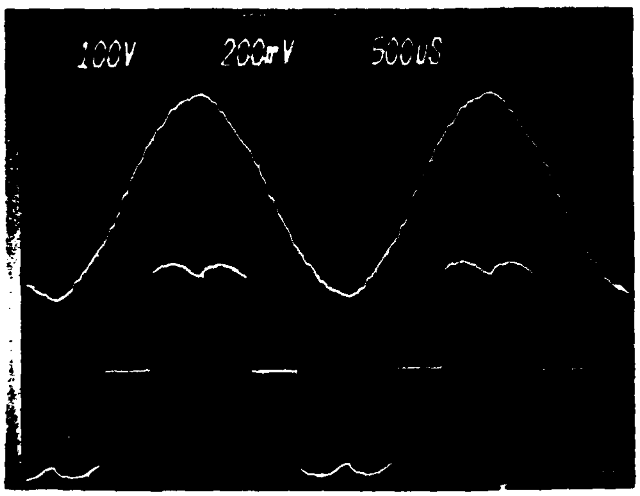
Delco Electronics

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION ______

V1 VØA 100V/DIV
V2 IØA 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 16-06-01
PIX NO. 1

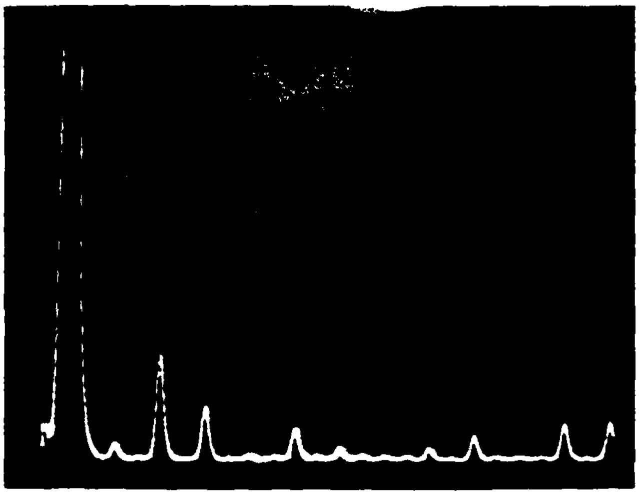


V1 VØB 100V/DIV
V2 IØB 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 16-06-01
PIX NO. 2

V1 VØC 100V/DIV
V2 IØC 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 16-06-01
PIX NO. 3

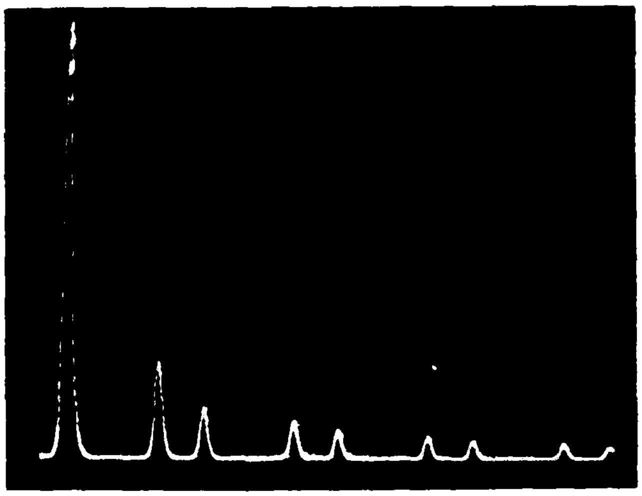
Delco Electronics

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION ______

V1 SPECTRUM VØA
V2 1%/DIV
V3 ______
V4 ______
H1 1KHZ/DIV
H2 ______
TEST NO. 16-06-01
PIX NO. 4



V1 SPECTRUM IØA
V2 10%/DIV
V3 ______
V4 ______
H1 1KHZ/DIV
H2 ______
TEST NO. 16-06-01
PIX NO. 5

V1 ______
V2 ______
V3 ______
V4 ______
H1 ______
H2 ______
TEST NO. ______
PIX NO. ______

R82-127
SSP

Delco Electronics

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 12.5KVA, 400HZ, 120/208V M-G Set

MFGR Electric Machinery Mfg. Co.

MODEL NO.

SERIAL NO. 1Q144072/3

TEST DESCRIPTION M-G SET OUTPUT WAVEFORM WITH NON-LINEAR LOADING

REF: 10KW

TEST NO. 17-06-04

SHEET 1 OF 4

DATE 17-JUN-82

PROJ ENGR A.H. BARRETT

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	VØA (TRUE RMS)	YEW 2505	120.4		120.4 VRMS		1,4,5		
(b)	VØB	254447	123.6		123.6 VRMS		2		
(c)	VØC		122.4		122.4 VRMS		3		
(d)	IØA		26.73		26.73 ARMS		1, 6		
(e)	IØB		27.75		27.75 ARMS		2		
(f)	IØC		30.20		30.20 ARMS		3		
(g)	PØA		2932		2932 W	PF = 0.911			
(h)	PØB		3210		3210 W	PF = 0.936			
(i)	PØC		3424		3424 W	PF = 0.926			
(j)	PTOT		9560		9560 W				
(k)	VØA THD	HP 339A	12.5		12.5%		4,5		
(l)	VØB THD		10.4		10.4%				
(m)	VØC THD		10.7		10.7%				
(n)	IØA THD		27.5		27.5%		6		
(o)	IØB THD		27.8		27.8%				

NOTES: LOAD CONFIGURATION: SEE SHEET 2

$L = 30\mu H$ $C = 6600\mu F$

SSP2

Delco Electronics
SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 12.5 KVA, 400 Hz, 120/208V M-G SET

MFGR Electric Machinery Mfg. Co.

MODEL NO.

SERIAL NO. 1Ø244072/3

TEST DESCRIPTION M-G SET OUTPUT WAVEFORM WITH NON-LINEAR LOADING

REF:

TEST NO. 17-06-04

SHEET 2 OF 4

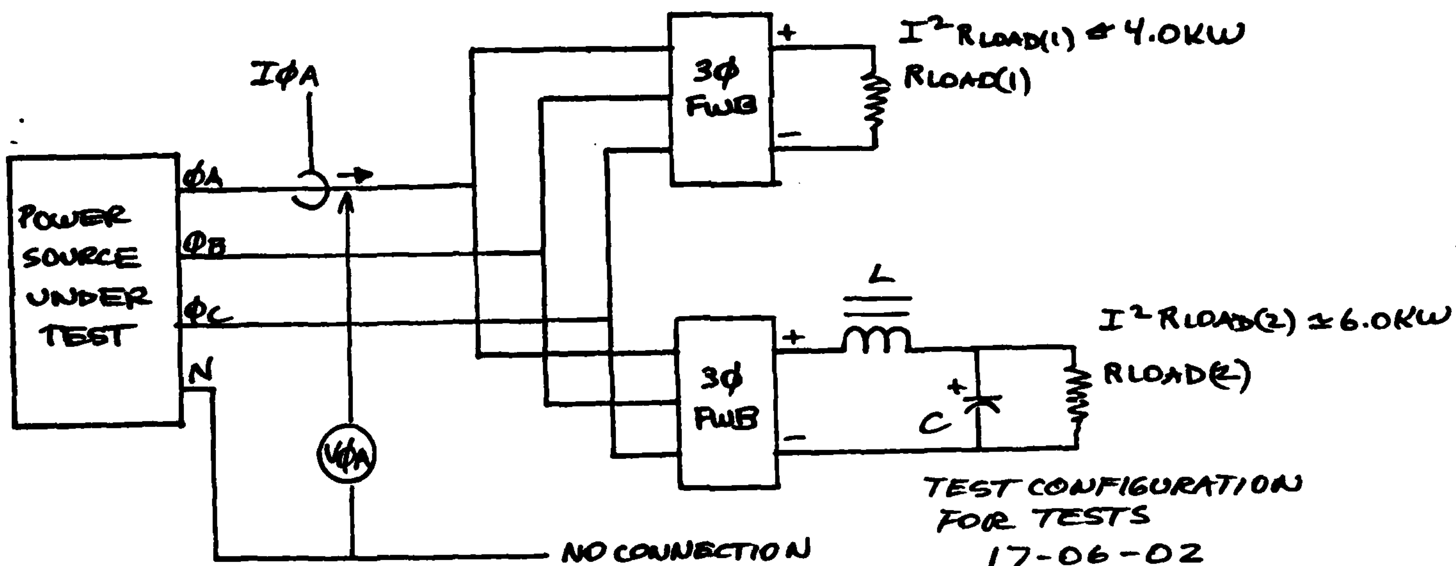
DATE 17-JUN-82

PROJ ENGR A.H. BARRETT

TEST BY

OBSERVER

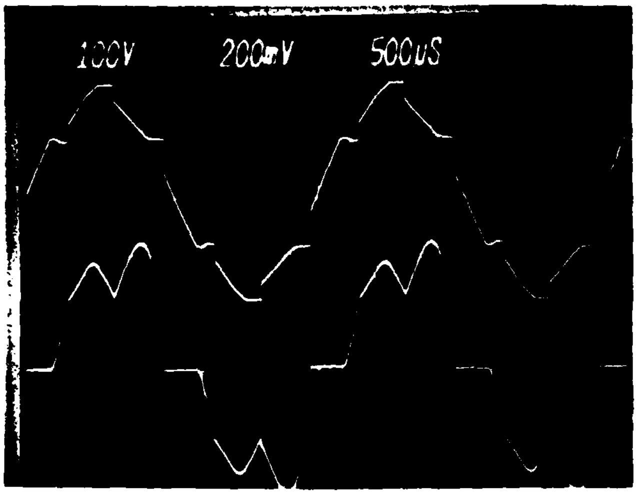
(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a) IØC THD	HP 339A	25.1		25.1%				



TEST CONFIGURATION FOR TESTS 17-06-02 THRU 17-06-05

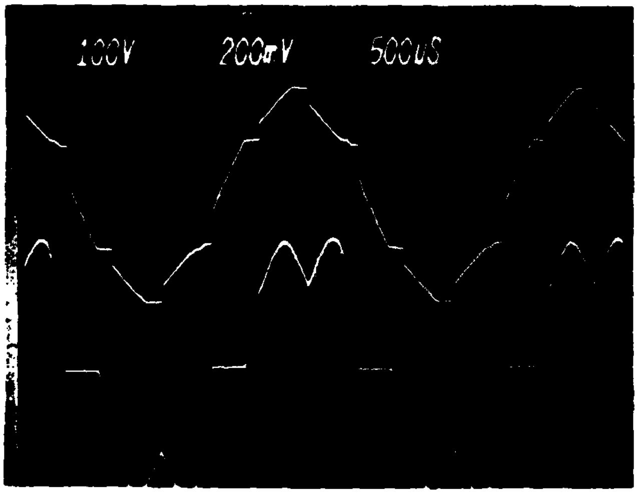
Delco Electronics

SANTA BARBARA, CALIFORNIA

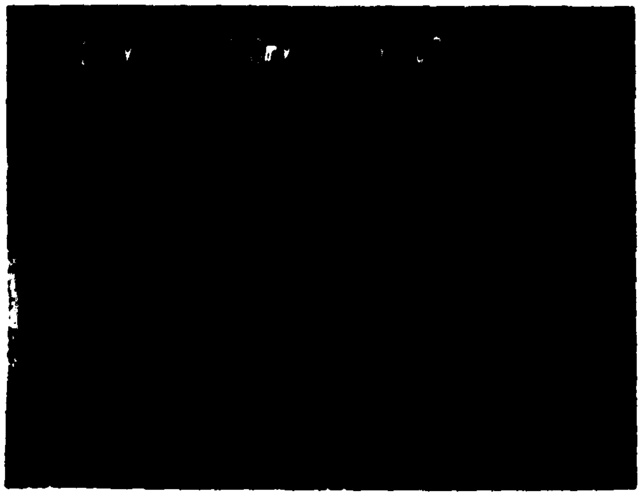


TEST DESCRIPTION ____________

V1 VØA 100V/DIV
V2 IØA 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 17-06-04
PIX NO. 1

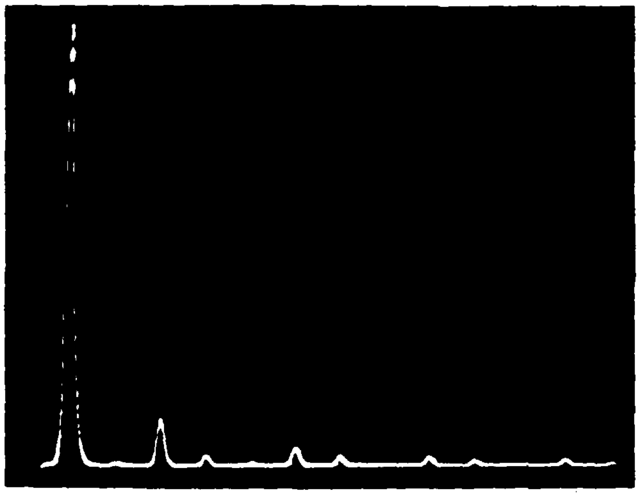


V1 VØB 100V/DIV
V2 IØB 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 17-06-04
PIX NO. 2



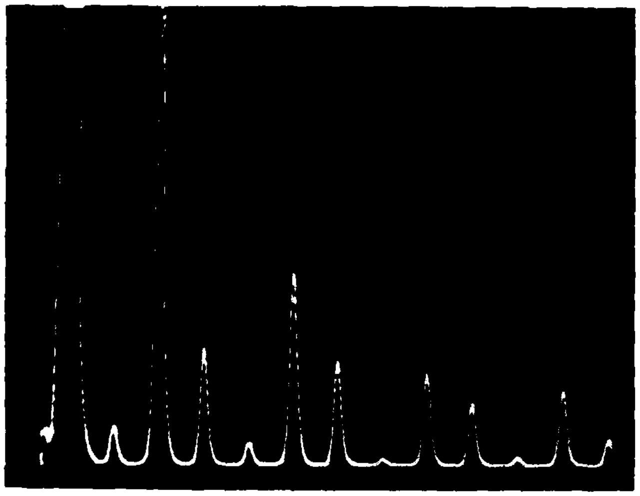
V1 VØC 100V/DIV
V2 IØC 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 17-06-04
PIX NO. 3

SANTA BARBARA, CALIFORNIA

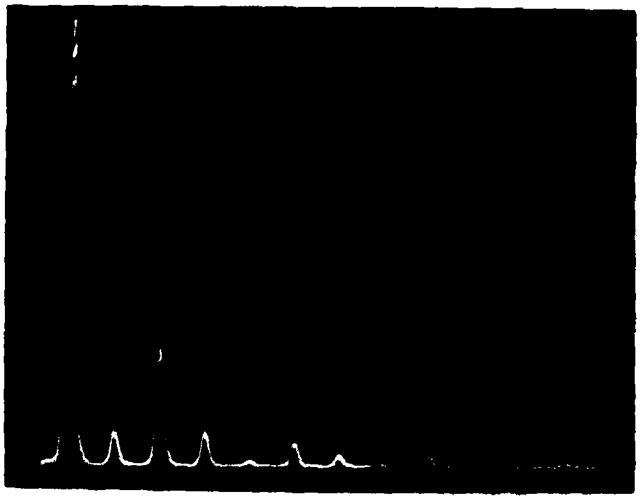


TEST DESCRIPTION ______

V1 SPECTRUM VØA
V2 10%/DIV
V3
V4
H1 1KHz/DIV
H2
TEST NO. 17-06-04
PIX NO. 4



V1 SPECTRUM VØA
V2 10%/DIV
V3
V4
H1 1KHz/DIV
H2
TEST NO. 17-06-04
PIX NO. 5



V1 SPECTRUM IØA
V2 10%/DIV
V3
V4
H1 1KHz/DIV
H2
TEST NO. 17-06-04
PIX NO. 6

R82-127

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 10KW FIREFINDER PCU/ TURBINE/ALT
MFGR DELCO
MODEL NO. TBU D423A
SERIAL NO. TEST BED UNIT 1

TEST DESCRIPTION INVERTER OUTPUT WAVEFORM WITH NON-LINEAR LOADING
REF: DRW

TEST NO. 17-06-02
SHEET 1 OF 4
DATE 17-JUN-82
PROJ ENGR A.H. BARRETT
TEST BY
OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	VØA TRUE RMS	YEW 2505/2514-97	122.0		122.0 VRMS		1,4		
(b)	VØB		121.9		121.9 VRMS		2		
(c)	VØC		121.9		121.9 VRMS		3		
(d)	IØA		32.00		32.00 ARMS		1,5		
(e)	IØB		31.90		31.90 ARMS		2		
(f)	IØC		31.94		31.94 ARMS		3		
(g)	PØA		3373		3373 W	PF = 0.864			
(h)	PØB		3365		3365 W	PF = 0.865			
(i)	PØC		3365		3365 W	PF = 0.864			
(j)	PTOT		10100		10100 W				
(k)	VØA THD	HP 332A	5.32		5.32%		4		
(l)	VØB THD		5.25		5.25%				
(m)	VØC THD		5.29		5.29%				
(n)	IØA THD		51.0		51.0%		5		
(o)	IØB THD		51.2		51.2%				

NOTES: LOAD CONFIGURATION: SEE SHEET 2
L = 30 μH C = 6600 μF

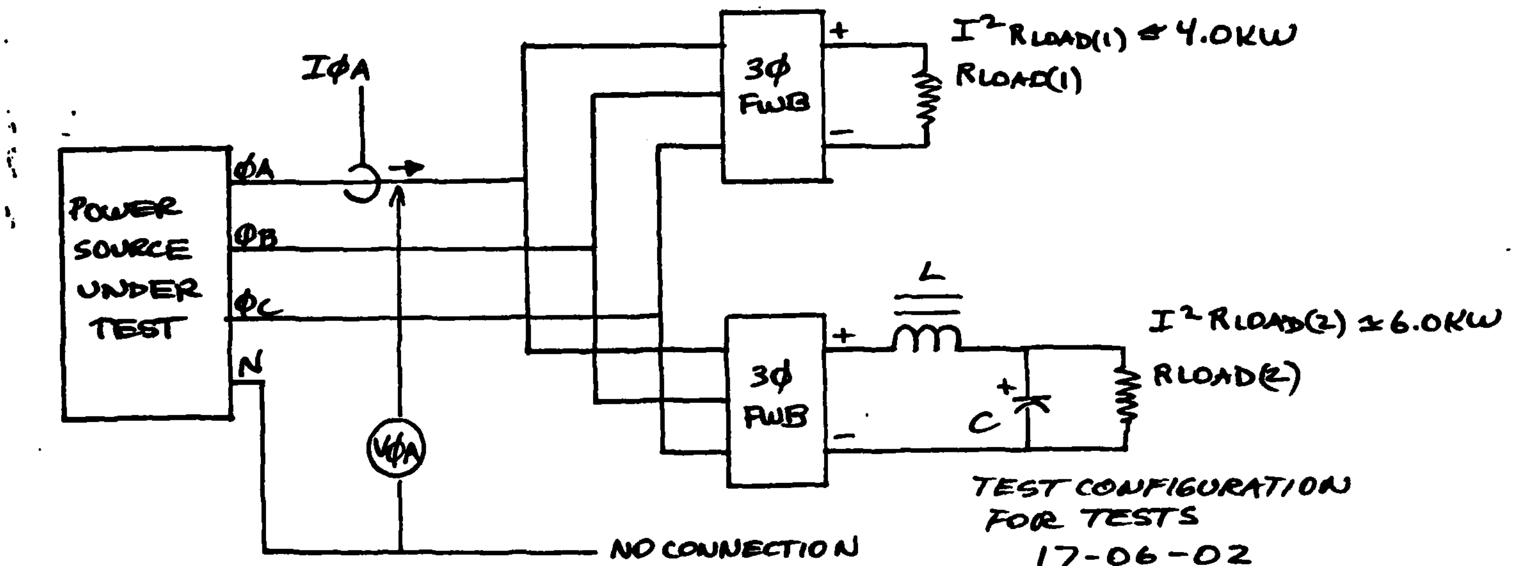
SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 10KW FIREFINDER PCU/ TURBINE/ALT
MFGR DELCO
MODEL NO. D423A
SERIAL NO. TEST BED UNIT 1

TEST DESCRIPTION INVERTER OUTPUT WAVEFORM WITH NON-LINEAR LOADING
REF:

TEST NO. 17-06-02
SHEET 2 OF 4
DATE 17-JUN-82
PROJ ENGR A.H. BARRETT
TEST BY
OBSERVER

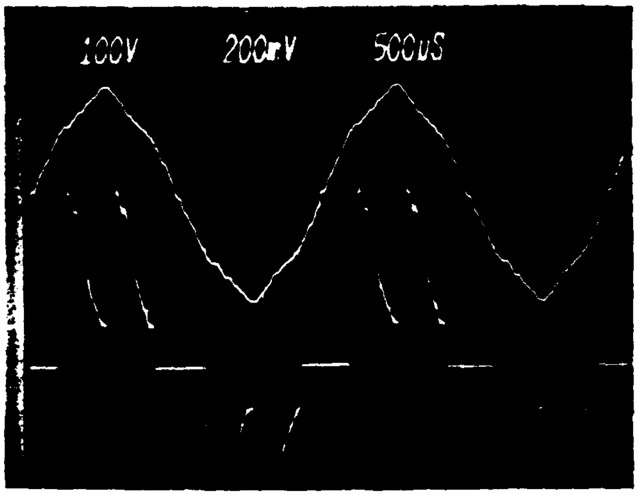
	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	IφC THD	HP 339A	51.3		51.3%				



TEST CONFIGURATION FOR TESTS 17-06-02 THRU 17-06-05

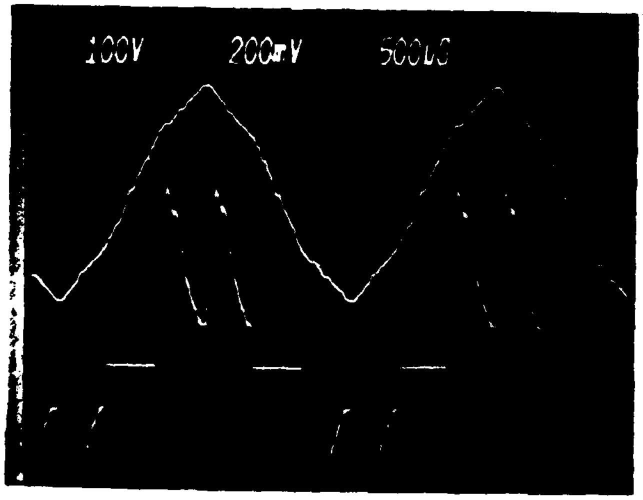
Delco Electronics

SANTA BARBARA, CALIFORNIA

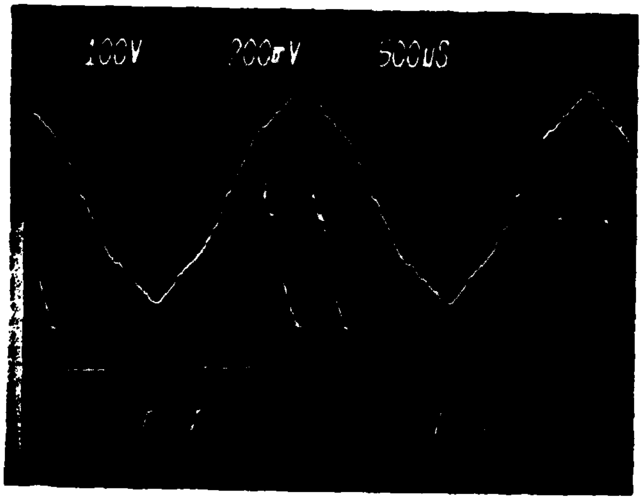


TEST DESCRIPTION ______

V1 VØA 100V/DIV
V2 IØA 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 17-06-02
PIX NO. 1



V1 VØB 100V/DIV
V2 IØB 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 17-06-02
PIX NO. 2

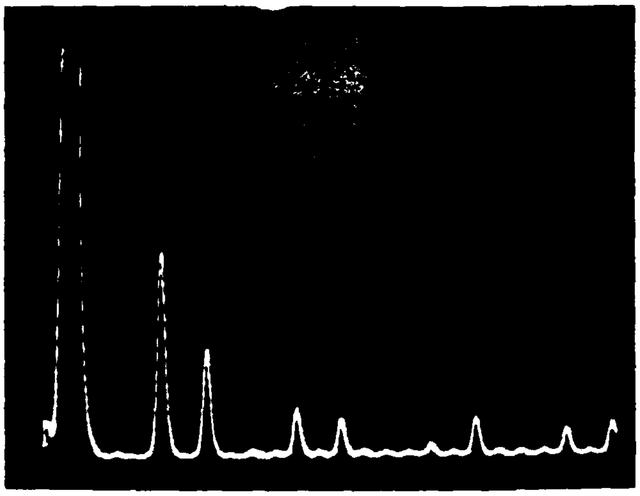


V1 VØC 100V/DIV
V2 IØC 20A/DIV
V3
V4
H1 500µs/DIV
H2
TEST NO. 17-06-02
PIX NO. 3

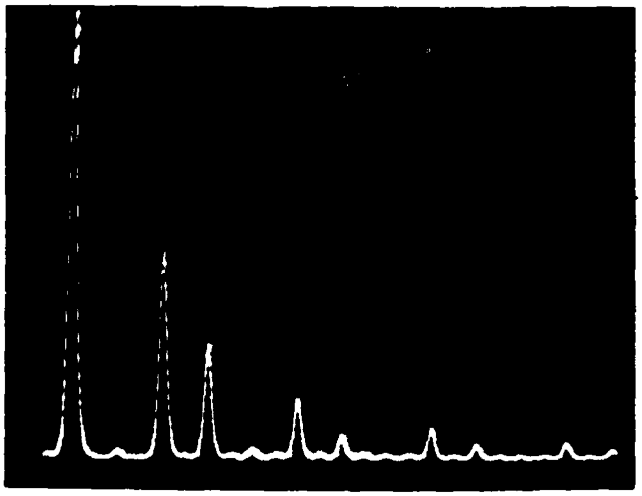
R82-127

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION



V1 SPECTRUM VØA
V2 10%/DIV
V3
V4
H1 1 KHZ/DIV
H2
TEST NO/17-06-02
PIX NO. 4



V1 SPECTRUM IØA
V2 10%/DIV
V3
V4
H1 1 KHZ
H2
TEST NO. 17-06-02
PIX NO. 5

V1
V2
V3
V4
H1
H2
TEST NO.
PIX NO.

Delco Electronics
SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 12.5KVA, 400Hz, 120/208V M-G Set

MFGR Electric Machinery Mfg. Co.

MODEL NO.

SERIAL NO. 1Q144072/3

TEST DESCRIPTION M-G SET OUTPUT WAVEFORM WITH NON-LINEAR LOADING

REF: 10KW

TEST NO. 17-06-05

SHEET 1 OF 4

DATE 17-JUN-82

PROJ ENGR A.H. BARRETT

TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	VØA (TRUE RMS)	YEW 2505/	121.5		121.5VRMS		1,4		
(b)	VØB	251447	124.0		124.0VRMS		2		
(c)	VØC		123.2		123.2VRMS		3		
(d)	IØA		27.05		27.05ARMS		1,5,6		
(e)	IØB		28.00		28.00ARMS		2		
(f)	IØC		29.42		29.42ARMS		3		
(g)	PØA		3057		3057 W	PF = 0.930			
(h)	PØB		3286		3286 W	PF = 0.946			
(i)	PØC		3400		3400 W	PF = 0.938			
(j)	PTOT		9740		9740 W				
(k)	VØA THD	HP 339A	12.1		12.1%		4		
(l)	VØB THD		9.8		9.8%				
(m)	VØC THD		9.8		9.8%				
(n)	IØA THD		24.3		24.3%		5,6		
(o)	IØB THD		24.6		24.6%				

NOTES: LOAD CONFIGURATION: SEE SHEET 2

L = 750μH C = 6600μF

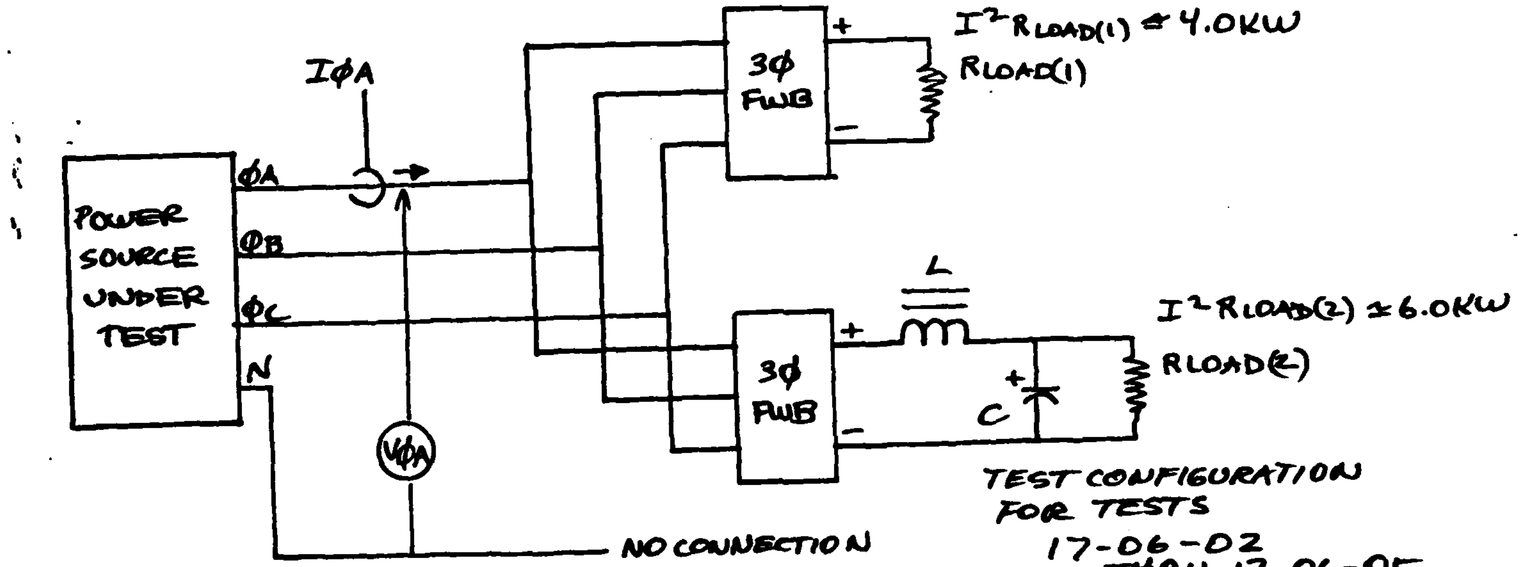
Delco Electronics
SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 12.5 KVA, 400 Hz, 120/208V M-G SET
MFGR Electric Machinery Mfg. Co.
MODEL NO.
SERIAL NO. L62440722/3

TEST DESCRIPTION M-G SET OUTPUT WAVEFORM WITH NON-LINEAR LOADINGS
REF:

TEST NO. 17-06-05
SHEET 2 OF 4
DATE 17-JUN-82
PROJ ENGR A.H. BARRETT
TEST BY
OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	IφC THD	HP 339A	22.6		22.6%				

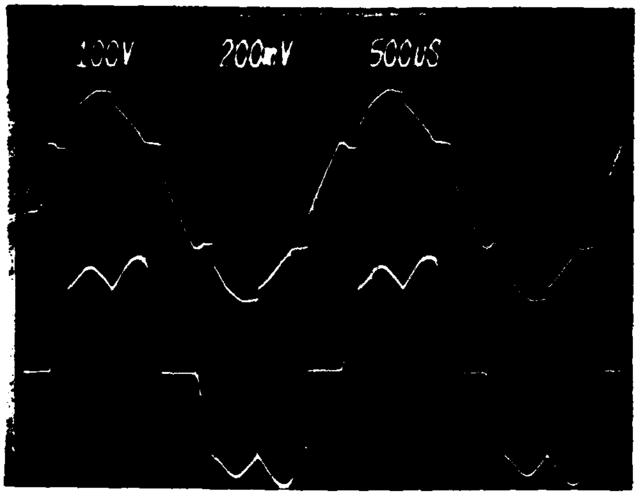


TEST CONFIGURATION FOR TESTS 17-06-02 THRU 17-06-05

Delco Electronics

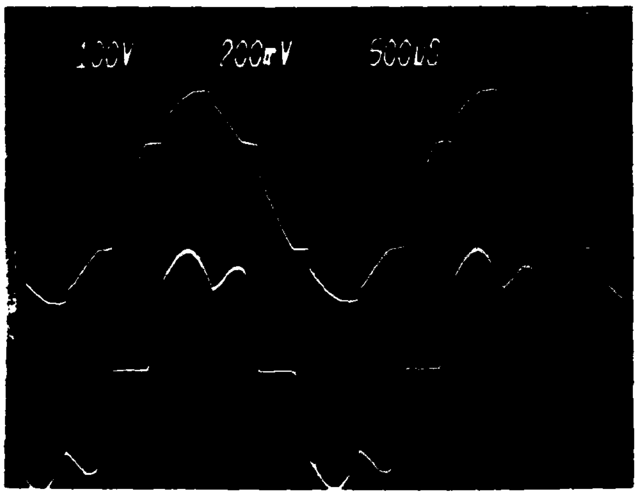
GM

SANTA BARBARA, CALIFORNIA

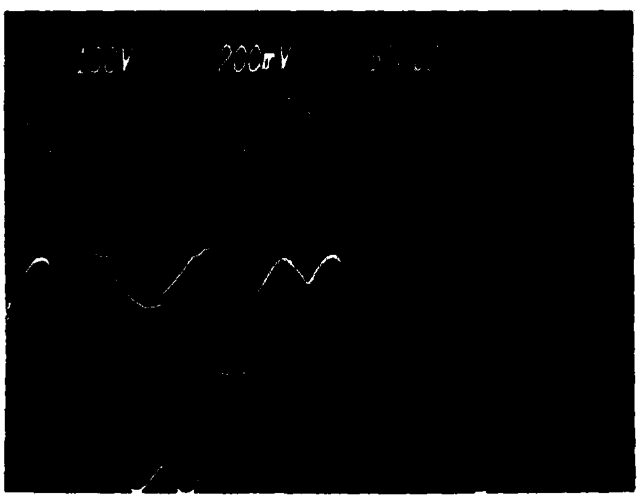


TEST DESCRIPTION ____________

V1 VØA 100V/DIV
V2 IØA 20A/DIV
V3
V4
H1 500μs/DIV
H2
TEST NO. 17-06-05
PIX NO. 1



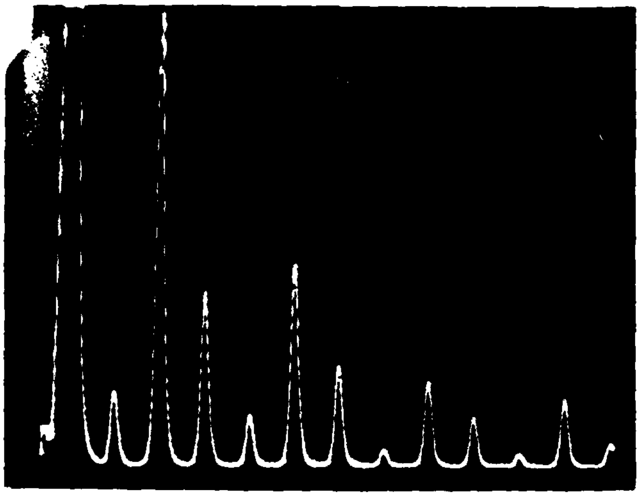
V1 VØB 100V/DIV
V2 IØB 20A/DIV
V3
V4
H1 500μs/DIV
H2
TEST NO. 17-06-05
PIX NO. 2



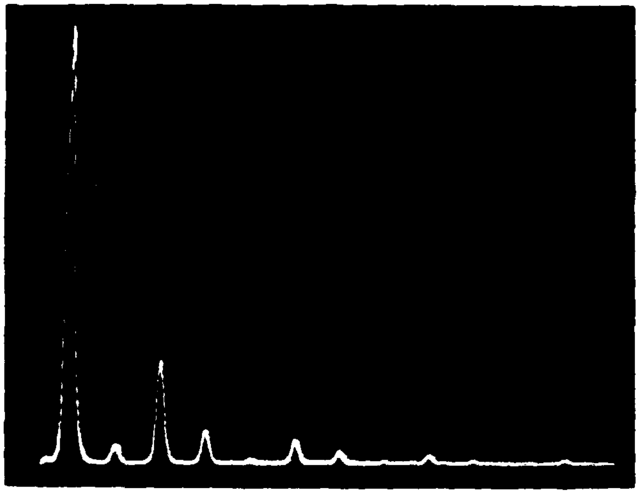
V1 VØC 100V/DIV
V2 IØC 20A/DIV
V3
V4
H1 500μs/DIV
H2
TEST NO. 17-06-05
PIX NO. 3

SANTA BARBARA, CALIFORNIA

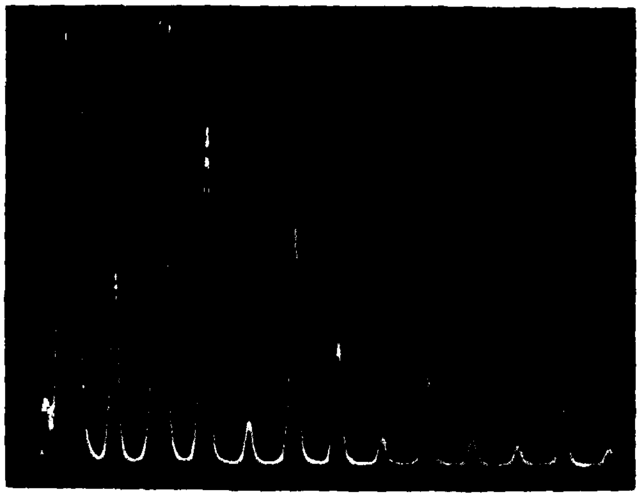
TEST DESCRIPTION ______



V1 SPECTRUM IØA
V2 10%/DIV
V3
V4
H1 1KHz/DIV
H2
TEST NO. 17-06-05
PIX NO. 4



V1 SPECTRUM IØA
V2 10%/DIV
V3
V4
H1 1KHz/DIV
H2
TEST NO. 17-06-05
PIX NO. 5



V1 SPECTRUM IØA
V2 10%/DIV
V3
V4
H1 1KHz/DIV
H2
TEST NO. 17-06-05
PIX NO. 6

R82-127

Delco Electronics GM

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 10KW FIREFINDER PCU/ TURBINE/ALT
MFGR DELCO
MODEL NO. TBU D423A
SERIAL NO. TEST BED UNIT 1

TEST DESCRIPTION INVERTER OUTPUT WAVEFORM WITH NON-LINEAR LOADING
REF: 10KW

TEST NO. 17-06-03
SHEET 1 OF 4
DATE 17-JUN-82
PROJ ENGR A.H. BARRETT
TEST BY
OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	VØA TRUE RMS	YEW 2505/	122.0		122.0VRMS		1,4		
(b)	VØB	2514-47	121.9		121.9VRMS		2		
(c)	VØC		121.8		121.8VRMS		3		
(d)	IØA		29.29		29.29ARMS		1,5		
(e)	IØB		29.26		29.26ARMS		2		
(f)	IØC		29.33		29.33ARMS		3		
(g)	PØA		3363		3363W	PF=0.941			
(h)	PØB		3357		3357W	PF=0.941			
(i)	PØC		3365		3365W	PF=0.942			
(j)	PTOT		10080		10080W				
(k)	VØA THD	HP 339A	3.60		3.60%		4		
(l)	VØB THD		3.60		3.60%				
(m)	VØC THD		3.58		3.58%				
(n)	IØA THD		30.4		30.4%		5		
(o)	IØB THD		30.6		30.6%				

NOTES: LOAD CONFIGURATIONS SEE SHEET 2
L = 750 μH   C = 6600 μF

SSP2

Delco Electronics — GM

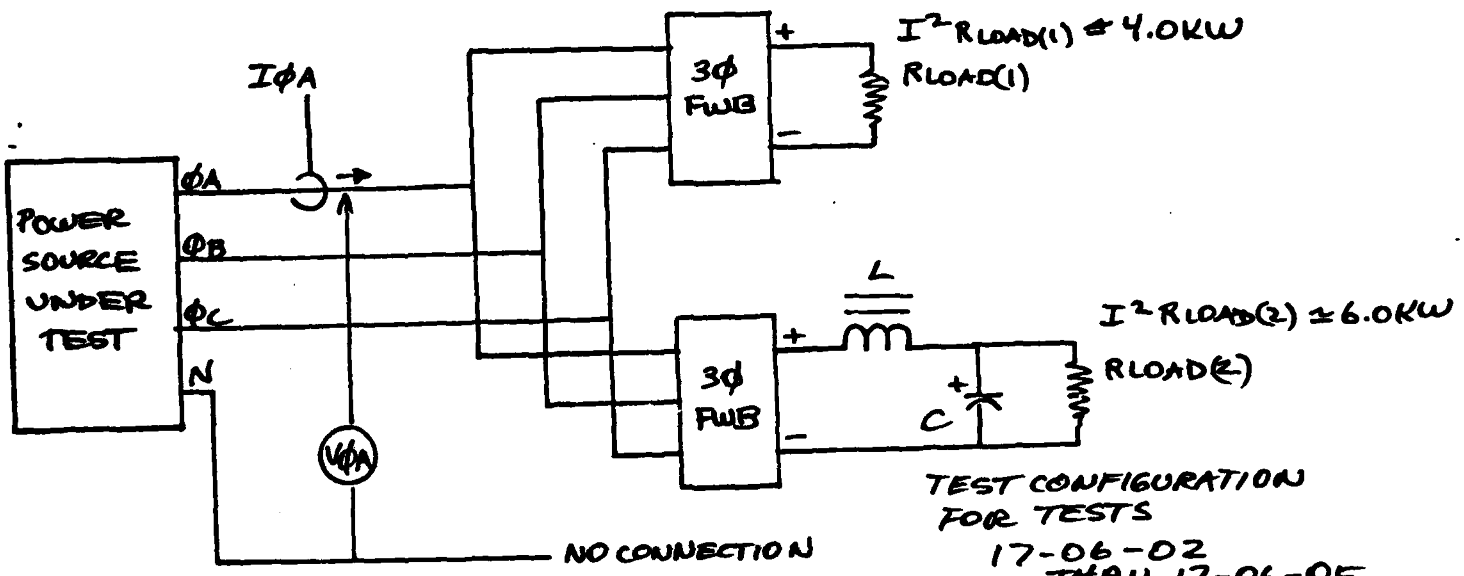
SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 10KW FIREFINDER PCU/ TURBINE/ALT
MFGR DELCO
MODEL NO. D423A
SERIAL NO. TEST BED UNIT 1

TEST DESCRIPTION INVERTER OUTPUT WAVEFORM WITH NON-LINEAR LOADING
REF:

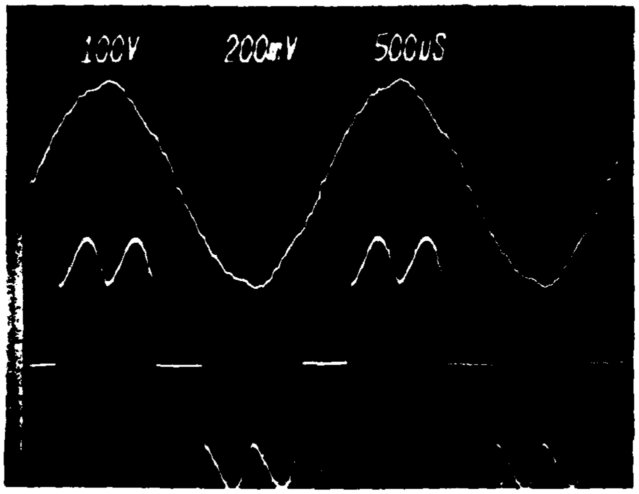
TEST NO. 17-06-03
SHEET 2 OF 4
DATE 17-JUN-82
PROJ ENGR A.H. BARRETT
TEST BY
OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	IϕC THD	HP 339A	30.4		30.4%				



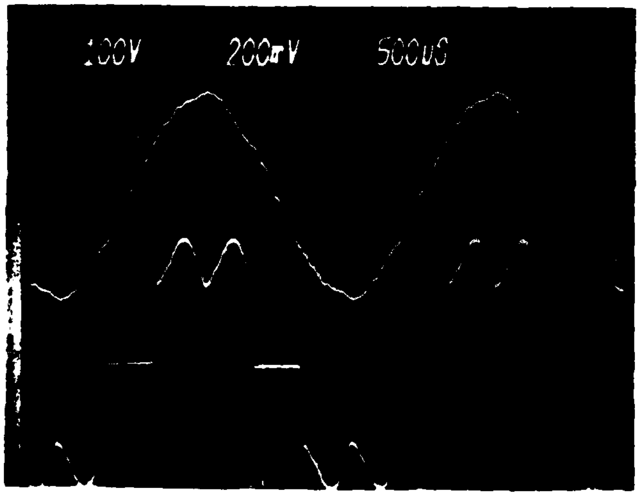
TEST CONFIGURATION FOR TESTS 17-06-02 THRU 17-06-05

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION ______

V1 VØA 100V/DIV
V2 IØA 20A/DIV
V3
V4
H1 1 KHz/DIV
H2
TEST NO. 17-06-03
PIX NO. 1



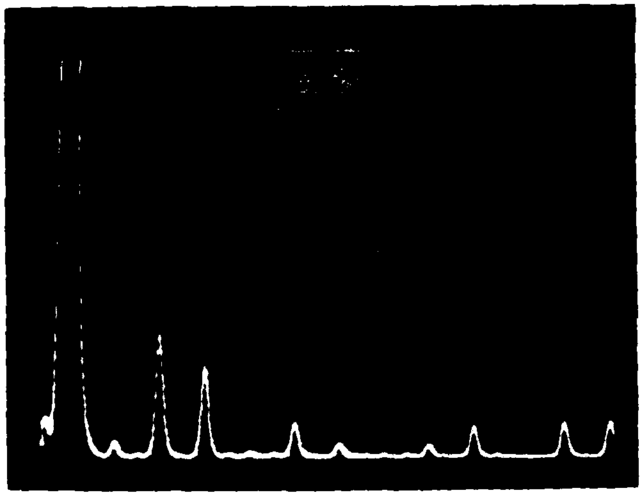
V1 VØB 100V/DIV
V2 IØB 20A/DIV
V3
V4
H1 1 KHz/DIV
H2
TEST NO. 17-06-03
PIX NO. 2

V1 VØC 100V/DIV
V2 IØC 20A/DIV
V3
V4
H1 1 KHz/DIV
H2
TEST NO. 17-06-03
PIX NO. 3

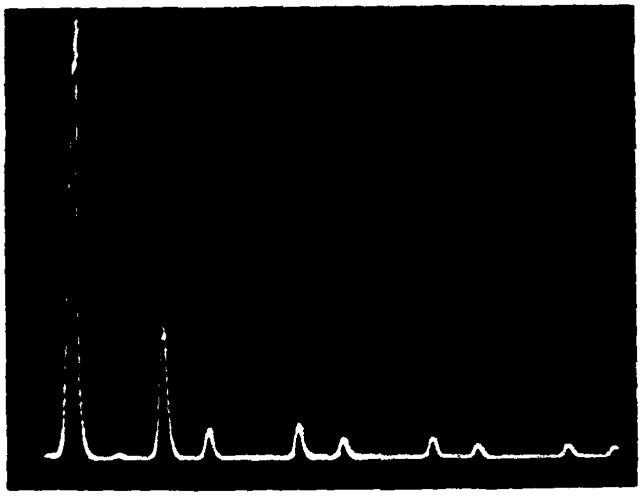
R82-127

SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION



V1 SPECTRUM VØA
V2 1%/DIV
V3
V4
H1
H2
TEST NO. 17-06-03
PIX NO. 4



V1 SPECTRUM IØA
V2 10%/DIV
V3
V4
H1
H2
TEST NO. 17-06-03
PIX NO. 5

V1
V2
V3
V4
H1
H2
TEST NO.
PIX NO.

TESTING WITH SINGLE PHASE NONLINEAR LOADING

Both the 15 kW Frequency Changer and the 10 kW Firefinder Generator Set (MEP D423A) were tested with balanced single phase nonlinear loads. These loads, consisting of single phase full wave bridge rectifiers with L-C filters and resistive loads, were connected in three- and four-wire wye configurations.

Figure J-1 shows a schematic diagram of the three-wire wye connected nonlinear load. Figure J-2 shows a schematic diagram of the four-wire wye connected load. This latter configuration rather closely simulates the type of loading caused by dc power supplies.

For test 24-05-03, the load circuit of Figure J-1 was used to load the 60 Hz utility power line of the Solid State Power Laboratory at the Delco plant. This load caused a line current total harmonic distortion (THD) of approximately 23 percent. For test 24-05-04, the load circuit of Figure J-2 was used to load the 60 Hz utility power line. The load caused a line current THD of approximately 44 percent. Due to source regulation, the voltage THD increased to approximately 2.6 percent with this nominally 9 kW load.

For test 24-05-05, the load circuit of Figure J-2 was used to load the 10 kW Firefinder Generator Set. The inductance value in this load is largely relative to the 400 Hz output of the Firefinder Set. With a line current THD, at 6 kW output, of approximately 37 percent, the output voltage THD was slightly less than 3 percent.

For test 24-05-06, the load circuit of Figure J-2 was used to load the 15 kW Frequency Changer. The output frequency tested was 400 Hz. (The 15 kW Frequency Changer does not start this load at 60 Hz.) With a line current THD of approximately 44 percent, the output voltage THD was approximately 5.5 percent. That the Frequency Changer has higher output distortion for this particular nonlinear load than the Firefinder Set is explained by the fact that the output circuit of the former has 60 Hz magnetics with higher impedance at 400 Hz than the latter which has 400 Hz magnetics.

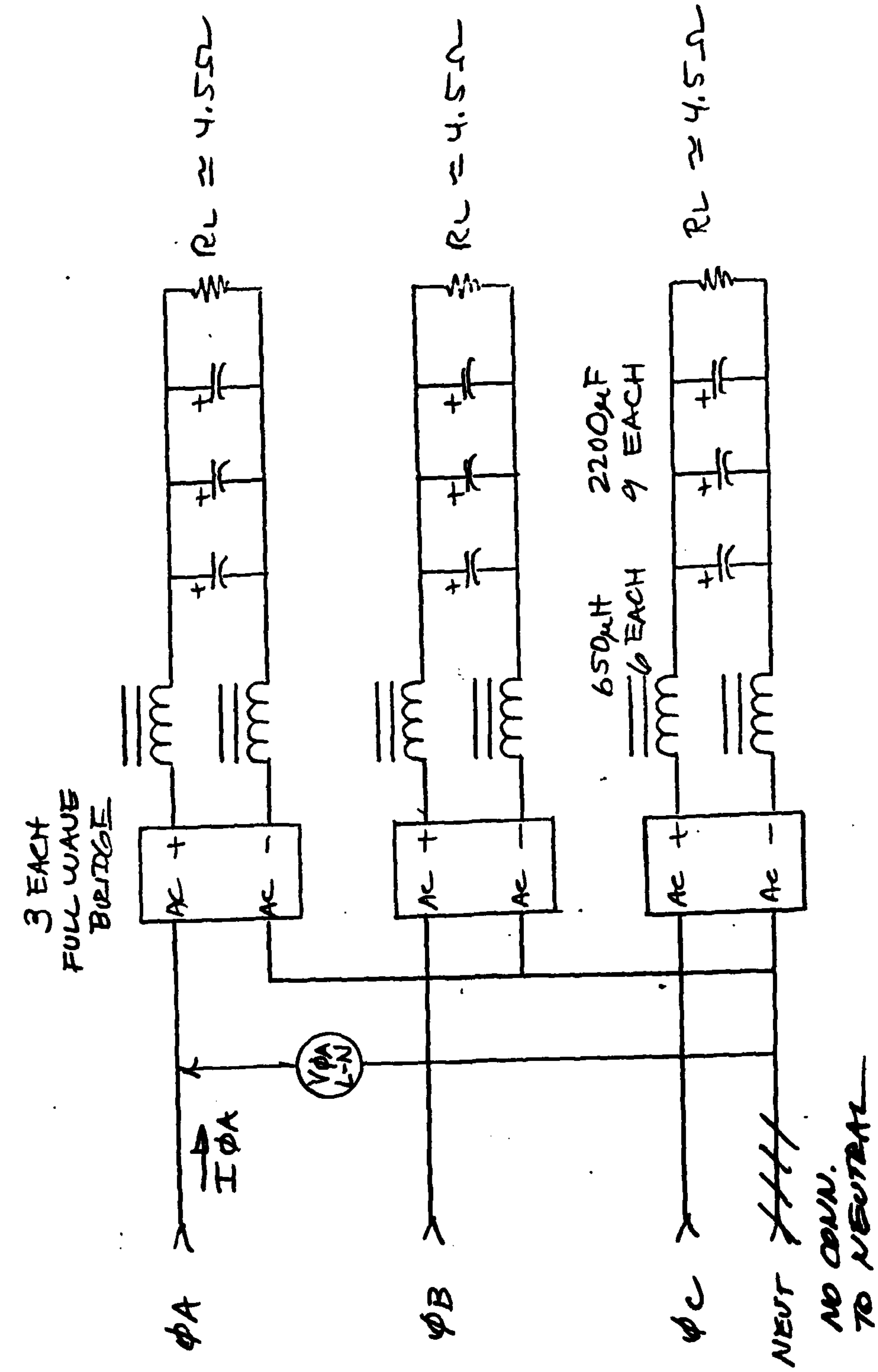


Figure J-1. Three-Wire Wye Connection, Test Configuration 1, Test 24-05-03

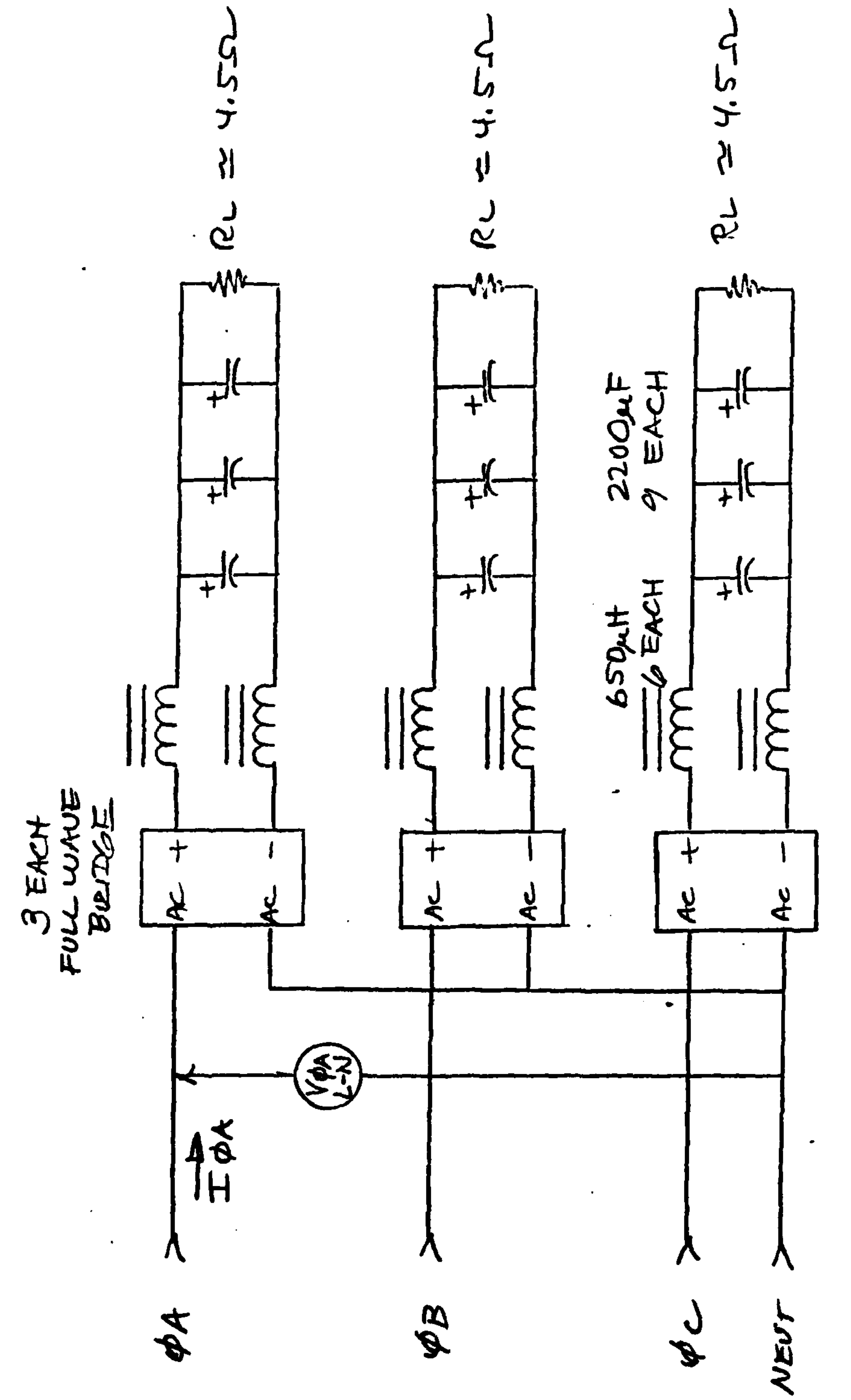


Figure J-2. Four-Wire Wye Connection, Test Configuration 1, Test 24-05-04

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 3ϕ RECT
TEST CONFIGURATION 1
BUT FLOATING NEUTRAL
MFGR
MODEL NO.
SERIAL NO.

TEST DESCRIPTION INPUT , V-I-PWR

REF: 8.6KW

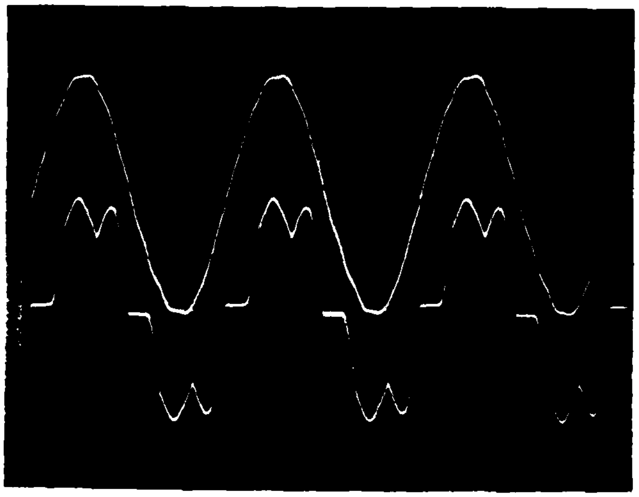
TEST NO. 24-5-C3
SHEET OF
DATE 24-MAY-1982
PROJ ENGR
TEST BY
OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ϕA VOLTAGE		120.0		120.0 V				
(b)	ϕA CURRENT		25.82		25.82 A				
(c)	ϕA PHASE ANGLE		—		— deg	PF = 0.922			
(d)	ϕA POWER		2858		2858 W				
(e)	ϕB VOLTAGE		120.3		120.3 V				
(f)	ϕB CURRENT		25.63		25.63 A				
(g)	ϕB PHASE ANGLE		—		— deg	PF = 0.920			
(h)	ϕB POWER		2835		2835 W				
(i)	ϕC VOLTAGE		119.6		119.6 V				
(j)	ϕC CURRENT		26.19		26.19 A				
(k)	ϕC PHASE ANGLE		—		— deg	PF = 0.920			
(l)	ϕC POWER		2881		2881 W				
(m)	CONV FREQUENCY		—		— Hz				
(n)									
(o)									

NOTES:
TEST CONFIGURATION 1 WITH FLOATING NEUTRAL

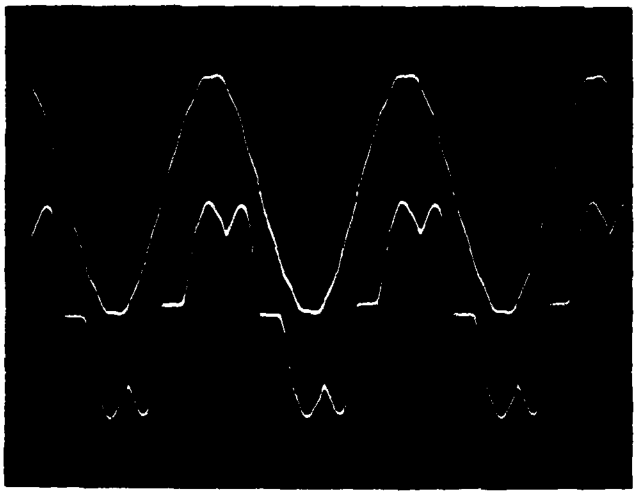
SP3

SANTA BARBARA, CALIFORNIA

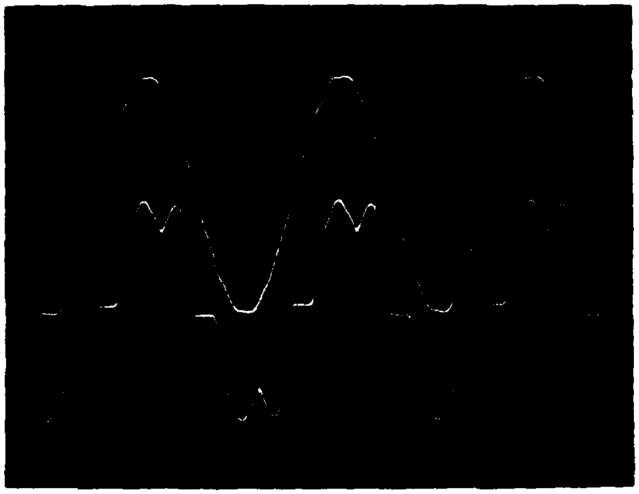


TEST DESCRIPTION VØxL-N & Iøx WAVEFORMS

V1 VØA L-N THD 1.88%
V2 IØA THD 23.4%
V3
V4
H1 5MS/DIV
H2
TEST NO. 24-5-03
PIX NO.



V1 VØB L-N THD=2.24%
V2 IØB THD=23.0%
V3
V4
H1 5MS/DIV
H2
TEST NO.
PIX NO.



V1 VØC L-N THD=1.82%
V2 IØC THD=22.4%
V3
V4
H1 5MS/DIV
H2
TEST NO.
PIX NO.

Delco Electronics

GM

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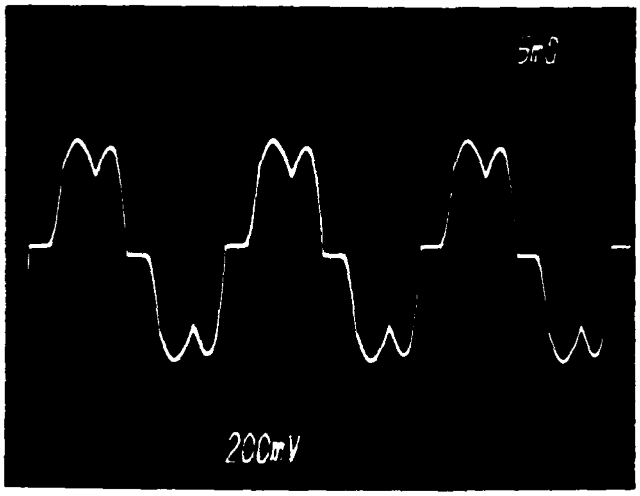
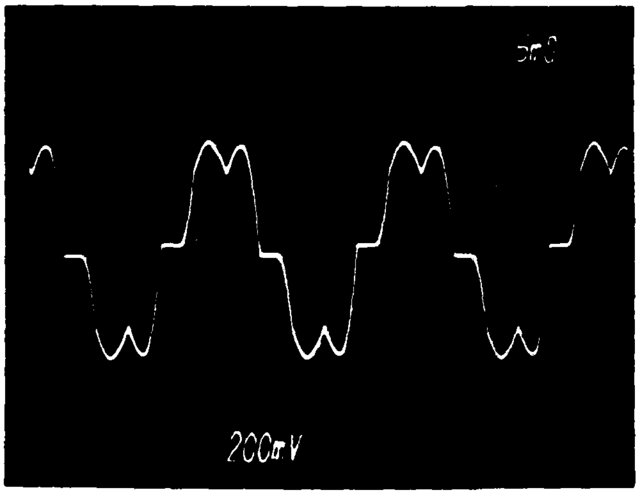
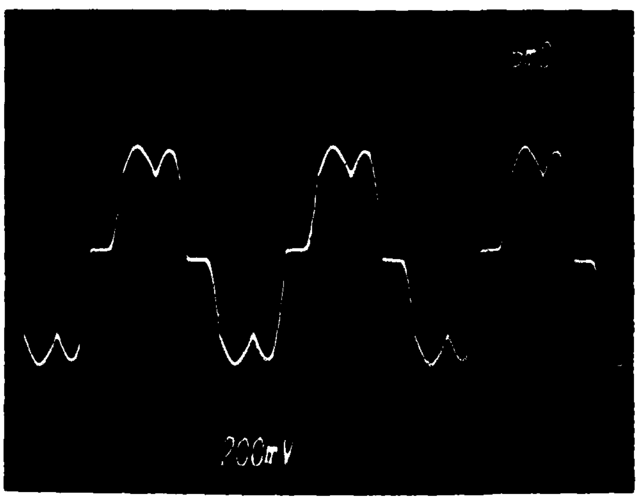


TEST DESCRIPTION $I\phi_x$
WAVEFORMS CALIB

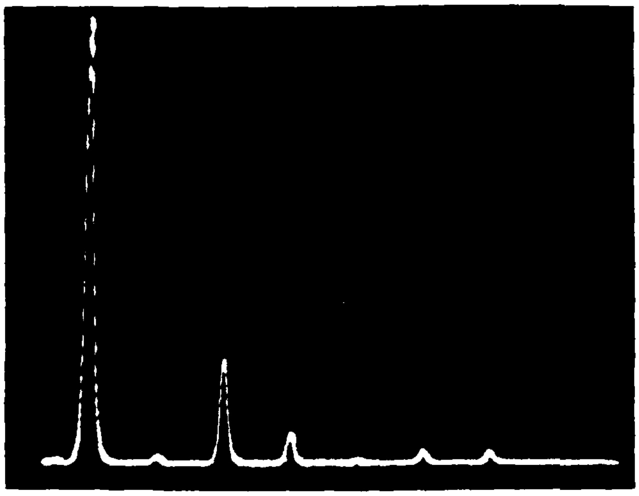
V1 $I\phi A$
V2 20A/DIV
V3
V4
H1 5MS/DIV
H2
TEST NO. 24-05-03
PIX NO.



V1 $I\phi B$
V2 20A/DIV
V3
V4
H1 5MS/DIV
H2
TEST NO.
PIX NO.



V1 $I\phi C$
V2 20A/DIV
V3
V4
H1 5MS/DIV
H2
TEST NO.
PIX NO.



SANTA BARBARA, CALIFORNIA

TEST DESCRIPTION IØx DISTORTION COMPONENTS

V1 IØA

V2 10% / DIV

V3

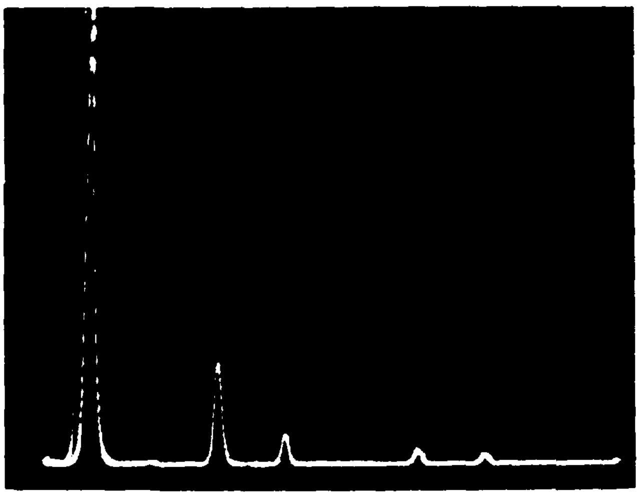
V4

H1 100Hz/DIV

H2

TEST NO. 24-5-03

PIX NO.



V1 IØB

V2

V3

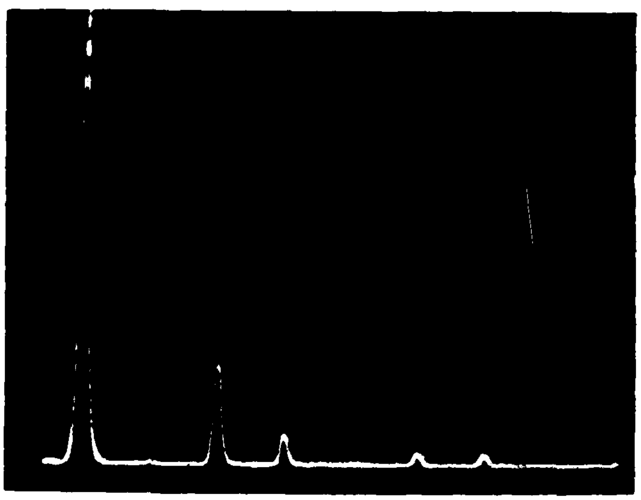
V4

H1

H2

TEST NO.

PIX NO.



V1 IØC

V2

V3

V4

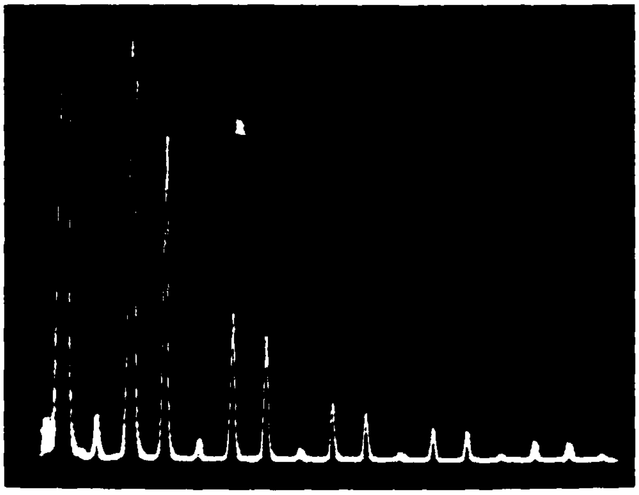
H1

H2

TEST NO.

PIX NO.

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION Iφx
DISTORTION COMPONENTS

V1 IφA

V2 1%/DIV

V3

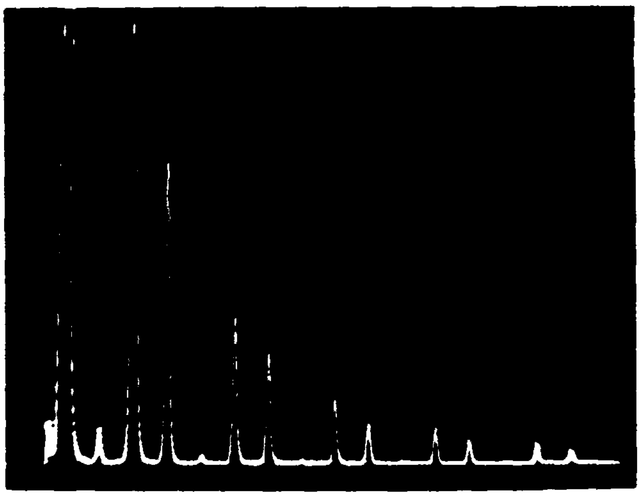
V4

H1 200Hz/DIV

H2

TEST NO. 24-5-03

PIX NO.



V1 IφB

V2

V3

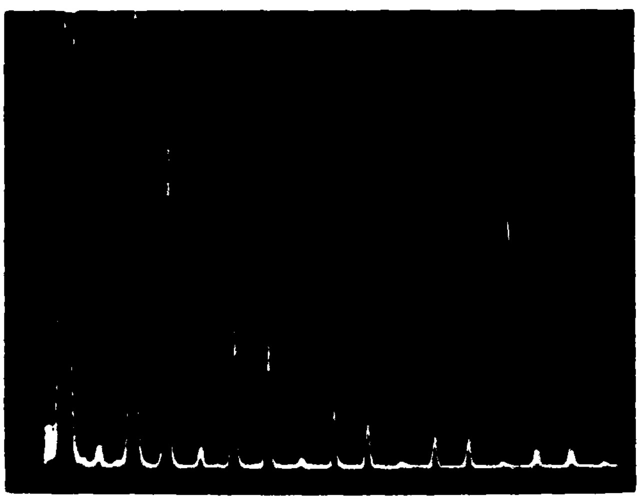
V4

H1

H2

TEST NO.

PIX NO.



V1 IφC

V2

V3

V4

H1

H2

TEST NO.

PIX NO.

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 3φ RECT
TEST CONFIGURATION 1
4 WIRE INPUT
MFGR
MODEL NO.
SERIAL NO.

TEST DESCRIPTION INPUT , V-I-PWR
REF:

TEST NO. 24-5-04
SHEET ___ OF ___
DATE 24-MAY-1982
PROJ ENGR
TEST BY
OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT φA VOLTAGE		119.7		119.7 V				
(b)	φA CURRENT		31.99		31.99 A		1		
(c)	φA PHASE ANGLE		—		— deg	PF = 0.792			
(d)	φA POWER		3032		3032 W				
(e)	φB VOLTAGE		119.8		119.8 V				
(f)	φB CURRENT		31.49		31.49 A		2		
(g)	φB PHASE ANGLE		—		— deg	PF = 0.792			
(h)	φB POWER		2989		2989 W				
(i)	φC VOLTAGE		119.2		119.2 V				
(j)	φC CURRENT		31.93		31.93 A		3		
(k)	φC PHASE ANGLE		—		— deg	PF = 0.796			
(l)	φC POWER		3028		3028 W				
(m)	CONV FREQUENCY		—		— Hz				
(n)	TOTAL POWER IN		9049W		9049 W				
(o)									

NOTES:

SIMULATES TYPICAL POWER SUPPLY LOAD

TEST CONFIGURATION 1

SSP3

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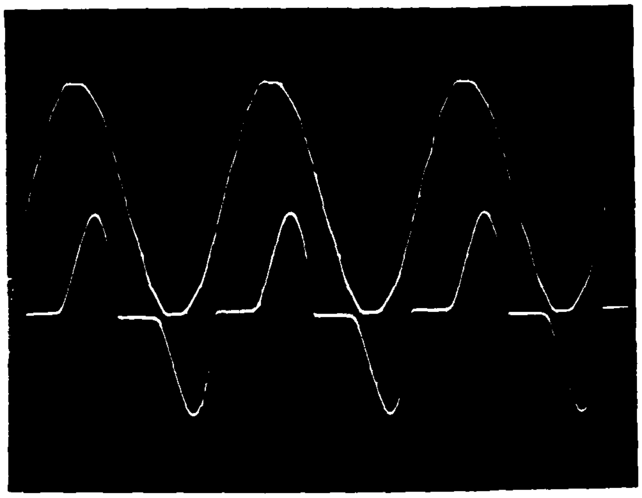


TEST DESCRIPTION VØx L-N & Iøx WAVEFORMS

V1 VØA L-N THD=2.469

V2 IØA THD=45.5%

V3

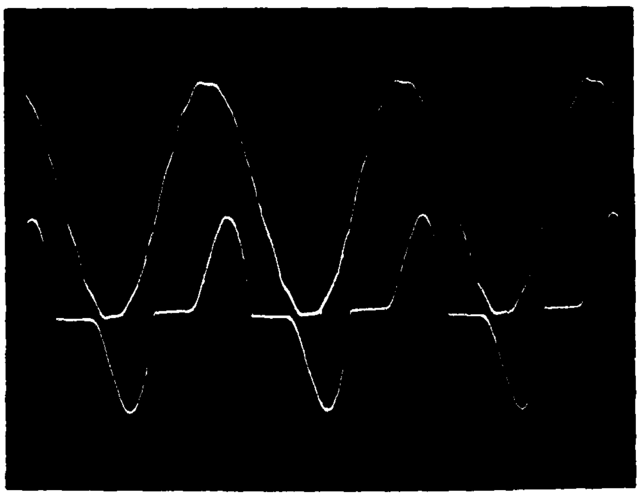
V4

H1 5MS/DIV

H2

TEST NO. 24-5-04

PIX NO. 1



V1 VØB L-N THD=2.53%

V2 IØB THD=43.5%

V3

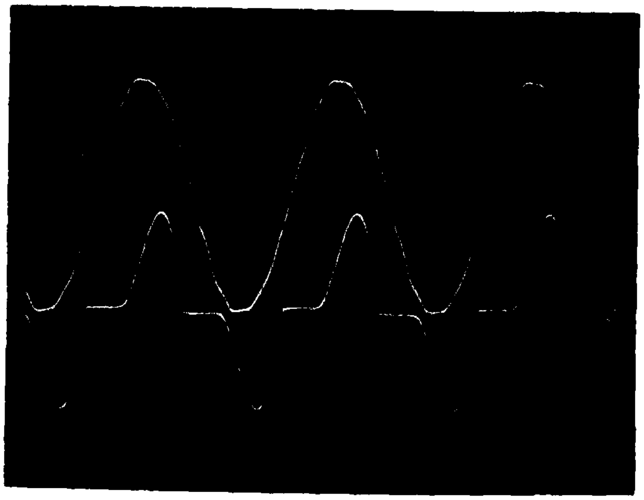
V4

H1 5MS/DIV

H2

TEST NO.

PIX NO. 2



V1 VØC L-N THD=2.65%

V2 IØC THD=42.5%

V3

V4

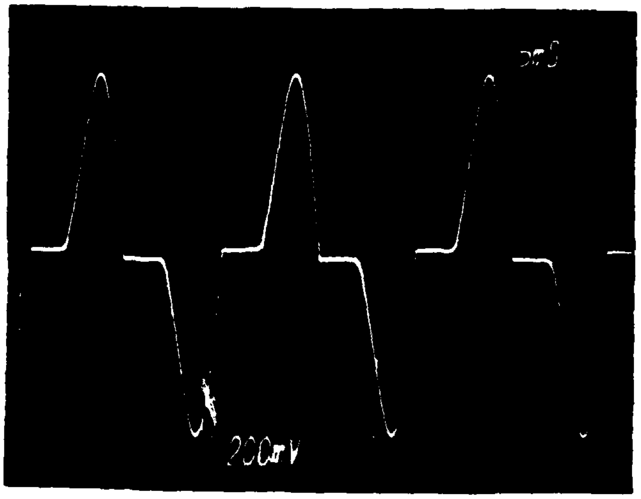
H1 5MS/DIV

H2

TEST NO.

PIX NO. 3

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION Iφx WAVEFORM, CAL'D

V1 IφA

V2 20A/DIV

V3

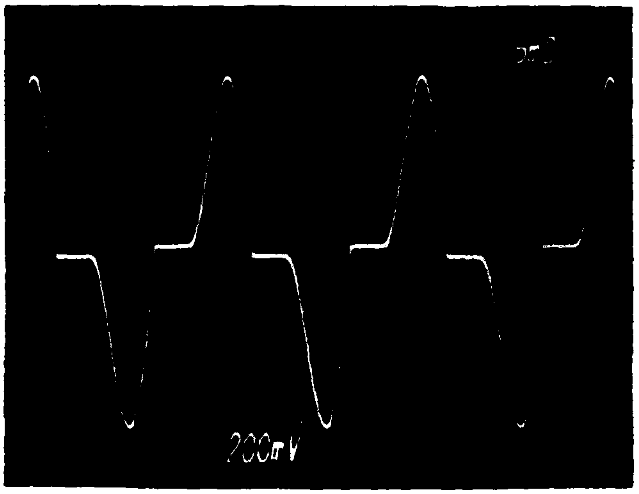
V4

H1

H2

TEST NO. 24-5-04

PIX NO.



V1 IφB

V2 20A/DIU

V3

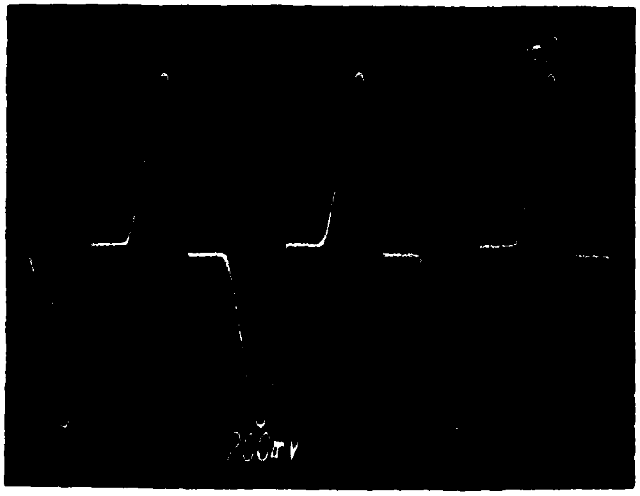
V4

H1

H2

TEST NO.

PIX NO.



V1 IφC

V2 20A/DIU

V3

V4

H1

H2

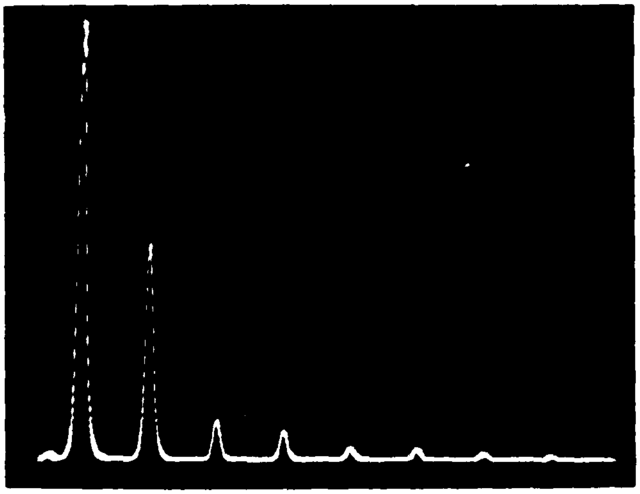
TEST NO.

PIX NO.

Delco Electronics

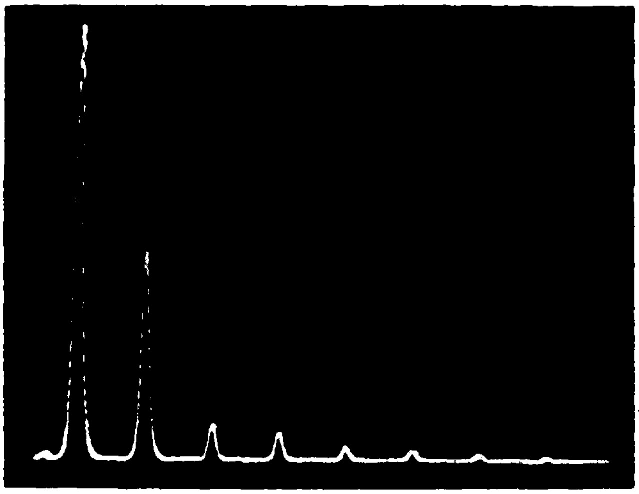
GM

SANTA BARBARA, CALIFORNIA

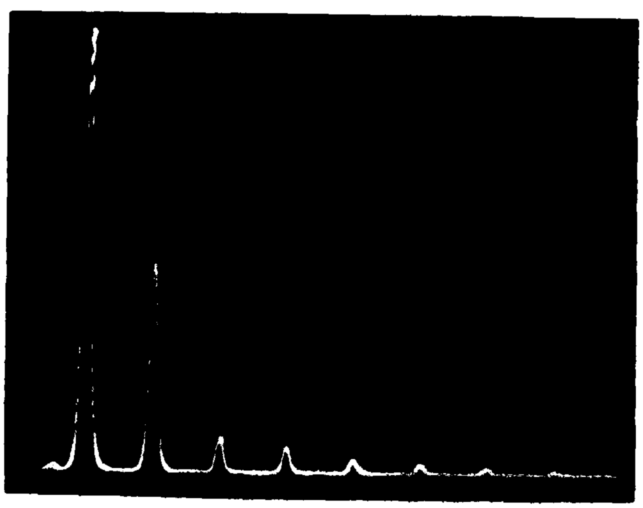


TEST DESCRIPTION IΦx
DISTORTION COMPONENTS

V1 IΦA
V2 10%/DIV
V3
V4
H1 100HZ/DIV
H2
TEST NO. 24-5-04
PIX NO.

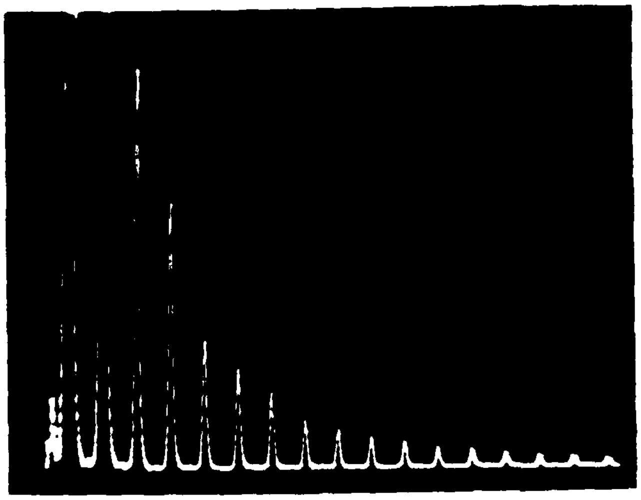


V1 IΦB
V2 10%/DIV
V3
V4
H1 100HZ/DIV
H2
TEST NO.
PIX NO.



V1 IΦC
V2 10%/DIV
V3
V4
H1 100HZ/DIV
H2
TEST NO.
PIX NO.

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION $I\phi x$ · DISTORTION COMPONENTS

V1 $I\phi A$

V2 1%/DIV

V3

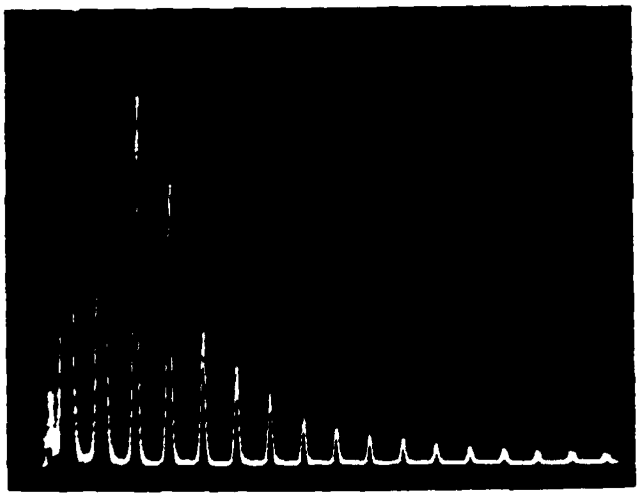
V4

H1 200 Hz/DIV

H2

TEST NO. 24-5-04

PIX NO.



V1 $I\phi B$

V2 1%/DIV

V3

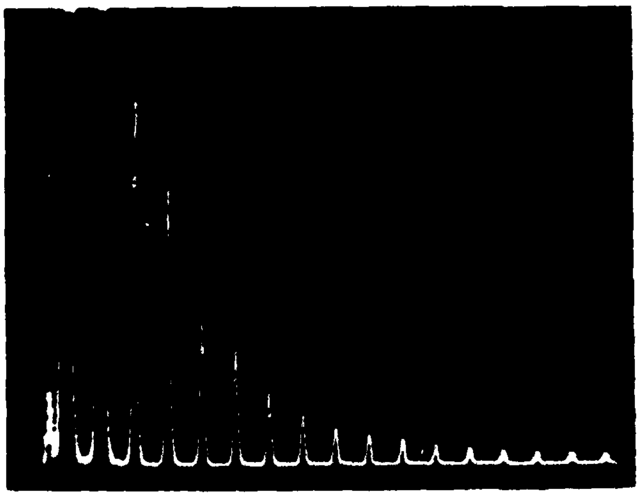
V4

H1 200Hz/DIV

H2

TEST NO.

PIX NO.



V1 $I\phi C$

V2 1%/DIV

V3

V4

H1 200Hz/DIV

H2

TEST NO.

PIX NO.

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION ____

MFGR DELCO

MODEL NO. FIBERUBER D423A

SERIAL NO. TEST BED UNIT

TEST DESCRIPTION INPUT , V-I-PWR

REF: ____

TEST NO. 24-5-05

SHEET ____ OF ____

DATE 24-MAY-1982

PROJ ENGR ____

TEST BY ____

OBSERVER ____

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ϕA VOLTAGE		120.5		120.5 V				
(b)	ϕA CURRENT		20.01		20.01 A				
(c)	ϕA PHASE ANGLE		—		— deg	PF = 0.839			
(d)	ϕA POWER		2024		2024 W				
(e)	ϕB VOLTAGE		120.5		120.5 V				
(f)	ϕB CURRENT		19.67		19.67 A				
(g)	ϕB PHASE ANGLE		—		— deg	PF = 0.854			
(h)	ϕB POWER		2024		2024 W				
(i)	ϕC VOLTAGE		120.4		120.4 V				
(j)	ϕC CURRENT		19.93		19.53 A				
(k)	ϕC PHASE ANGLE		—		— deg	PF = 0.854			
(l)	ϕC POWER		2049		2049 W				
(m)	CONV FREQUENCY				Hz				
(n)	TOTAL POWER		6097W		6097W				
(o)									

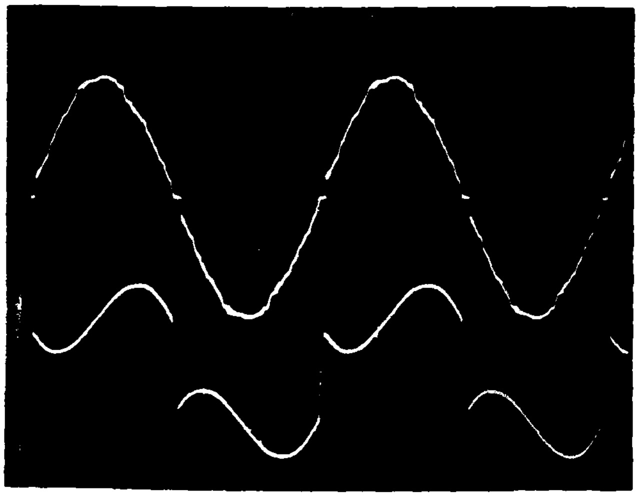
NOTES: ____

TEST CONFIGURATION 1

Delco Electronics

GM

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION V∅x L-N &
I∅x WAVEFORMS

V1 V∅A L-N THD= 2.98%

V2 I∅A THD= 36.9%

V3

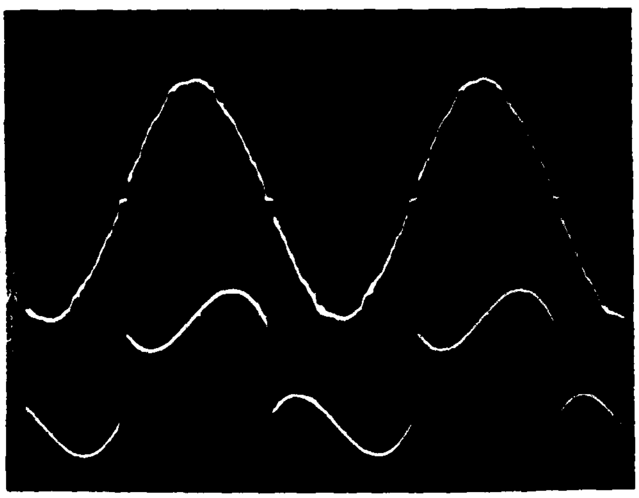
V4

H1 500μs/DIV

H2

TEST NO. 24-5-05

PIX NO.



V1 V∅B L-N THD=2.92%

V2 I∅B THD=37.2%

V3

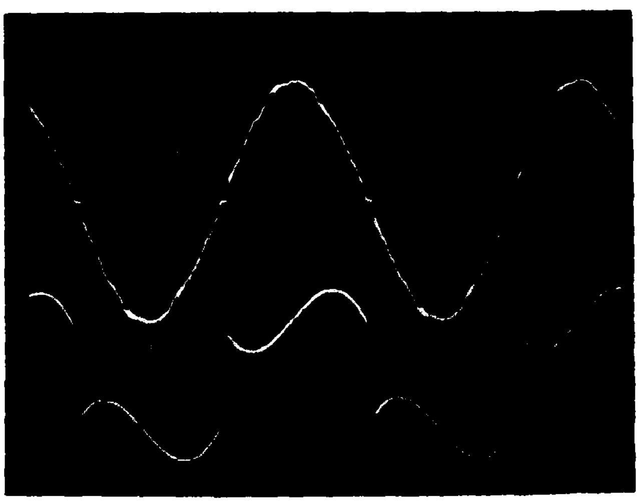
V4

H1

H2

TEST NO.

PIX NO.



V1 V∅c L-N THD=2.85%

V2 I∅c THD=37.1%

V3

V4

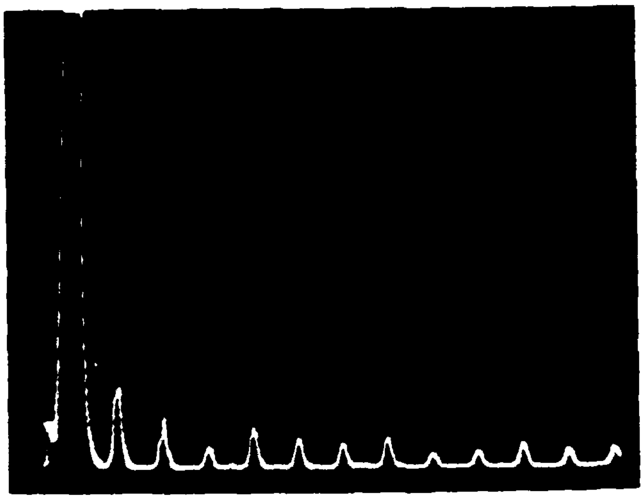
H1

H2

TEST NO.

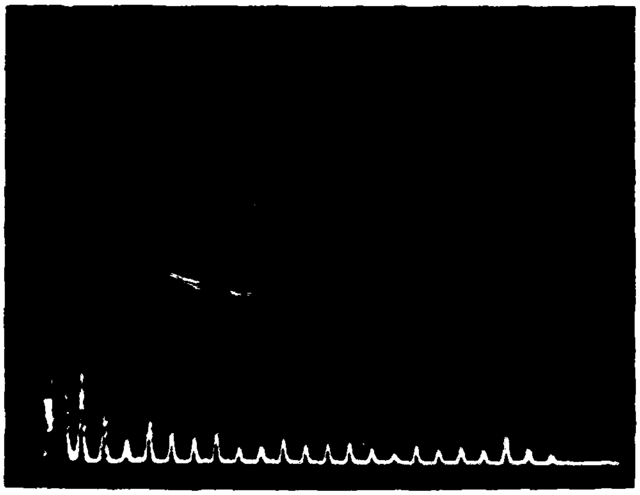
PIX NO.

SANTA BARBARA, CALIFORNIA

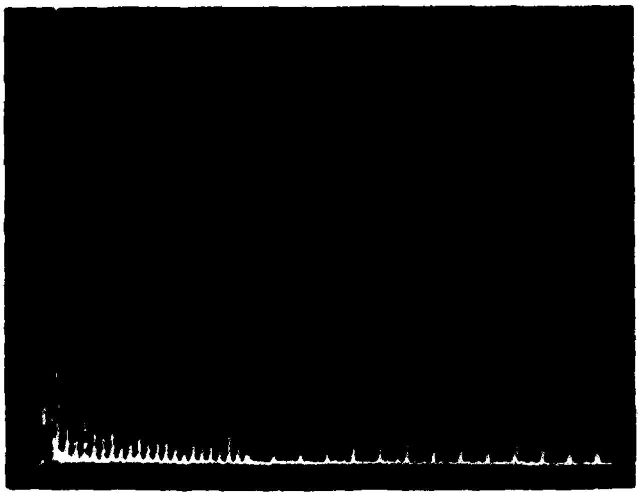


TEST DESCRIPTION VØx L-N
DISTORTION COMPONENTS

V1 VØA L-N
V2 1%/DIV
V3
V4
H1 1KHZ/DIV
H2
TEST NO. 24-5-05
PIX NO.

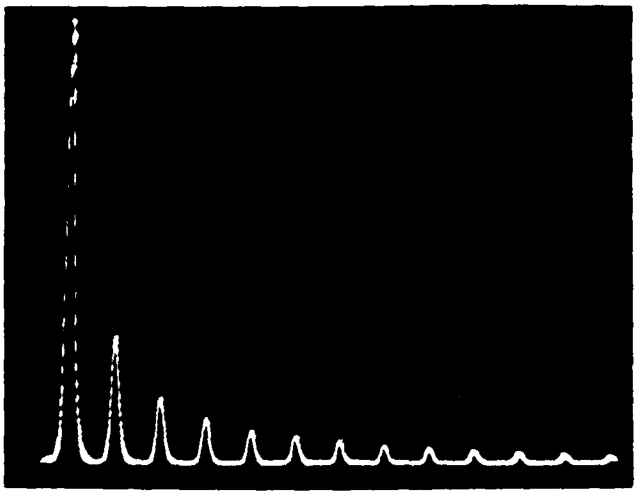


V1 VØA L-N
V2 1%/DIV
V3
V4
H1 2KHZ/DIV
H2
TEST NO.
PIX NO.

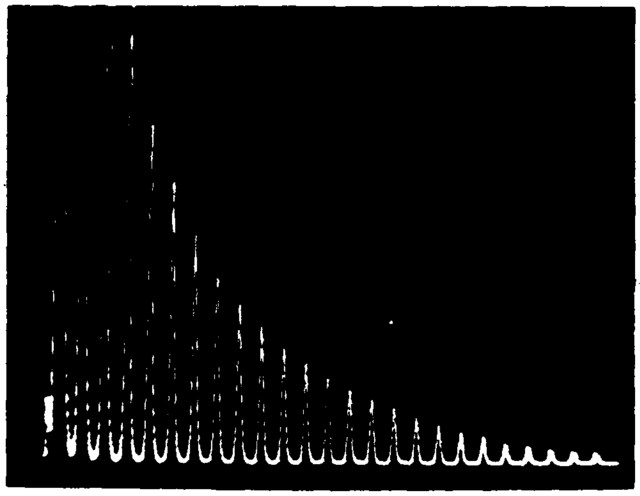


V1 VØA L-N
V2 1%/DIV
V3
V4
H1 5KHZ/DIV
H2
TEST NO.
PIX NO.

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION IØx
DISTORTION COMPONENTS
V1 IØA
V2 10%/DIV
V3
V4
H1 1KHZ/DIV
H2
TEST NO. 24-05-05
PIX NO.



V1 IØA
V2 10%/DIV
V3
V4
H1 2KHZ/DIV
H2
TEST NO.
PIX NO.

V1
V2
V3
V4
H1
H2
TEST NO.
PIX NO.

SANTA BARBARA, CALIFORNIA

EQUIP DESCRIPTION 15KW FREQ CHANGER 400HZ OUTPUT TO NON LINEAR LOAD

MFGR DELCO

MODEL NO.

SERIAL NO.

TEST DESCRIPTION INPUT , V–I–PWR

REF:

TEST NO. 24-5-06

SHEET ____ OF ____

DATE 24-MAY-1982

PROJ ENGR

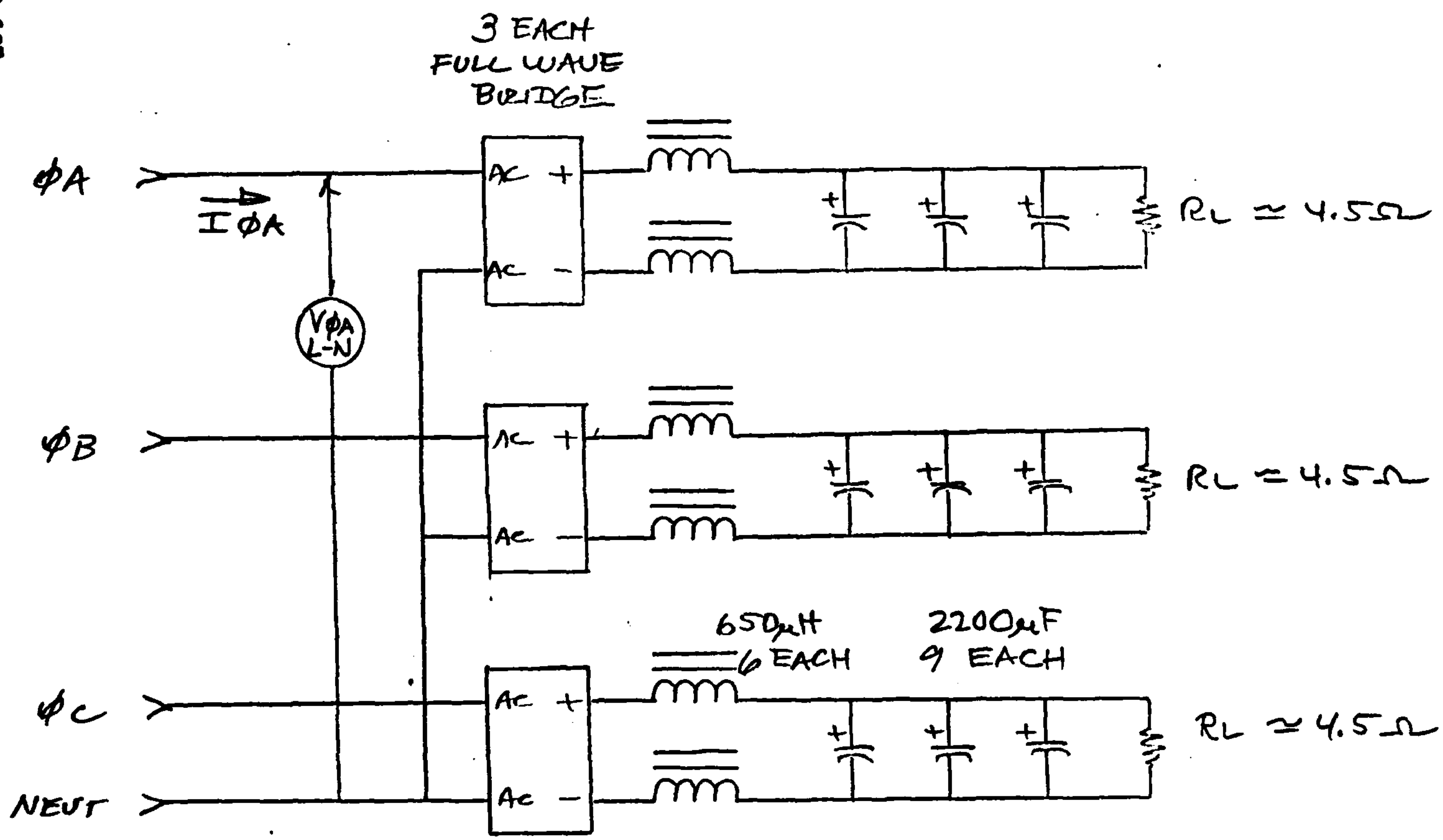
TEST BY

OBSERVER

	(1) MEASUREMENT	(2) INST NO.(s)	(3) RECORDED	(4) CORR FACTOR	(5) MEASURED	(6) CALCULATIONS/OTHER	(7) PIX NO.	(8) PERF	(9) SPEC
(a)	INPUT ΦA VOLTAGE		120.6		120.6 V				
(b)	ΦA CURRENT		19.98		19.98 A				
(c)	ΦA PHASE ANGLE				— deg	PF = 0.822			
(d)	ΦA POWER		1981		1981 W				
(e)	ΦB VOLTAGE		120.8		120.8 V				
(f)	ΦB CURRENT		19.68		19.68 A				
(g)	ΦB PHASE ANGLE				— deg	PF = 0.840			
(h)	ΦB POWER		1996		1996 W				
(i)	ΦC VOLTAGE		121.0		121.0 V				
(j)	ΦC CURRENT		19.98		19.98 A				
(k)	ΦC PHASE ANGLE		—		— deg	PF = 0.840			
(l)	ΦC POWER		2030		2030 W				
(m)	CONV FREQUENCY		—		— Hz				
(n)									
(o)									

NOTES:

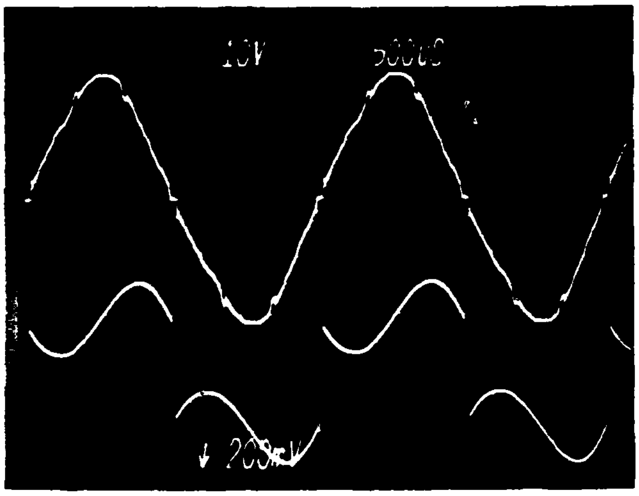
TEST CONFIGURATION 1



TEST CONFIGURATION 1
TEST NO. 24-5-06

Delco Electronics

SANTA BARBARA, CALIFORNIA



TEST DESCRIPTION 15KW
FREQ CHGR NON-LINEAR LOAD

V1 VØA L-N THD=5.5%

V2 IØA THD=44.0%

V3

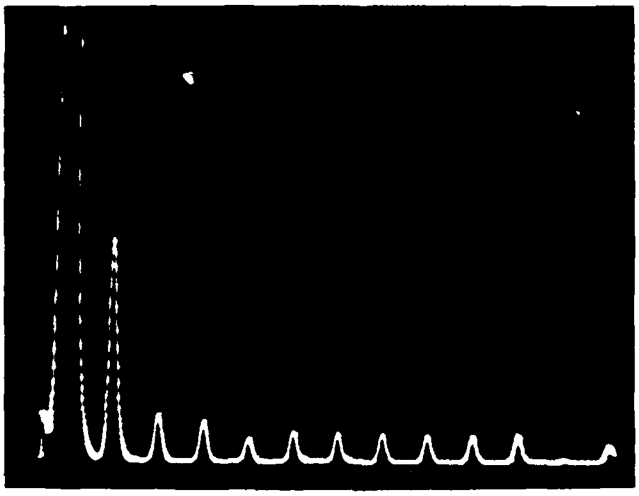
V4

H1 500μs/DIV

H2

TEST NO. 24-5-06

PIX NO.



V1 VØA L-N

V2 1%/DIV

V3

V4

H1 1KHz/DIV

H2

TEST NO.

PIX NO.

V1

V2

V3

V4

H1

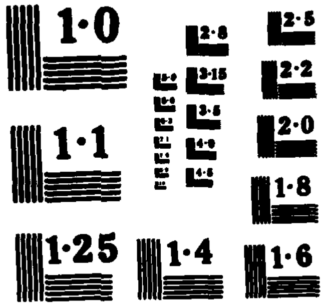
H2

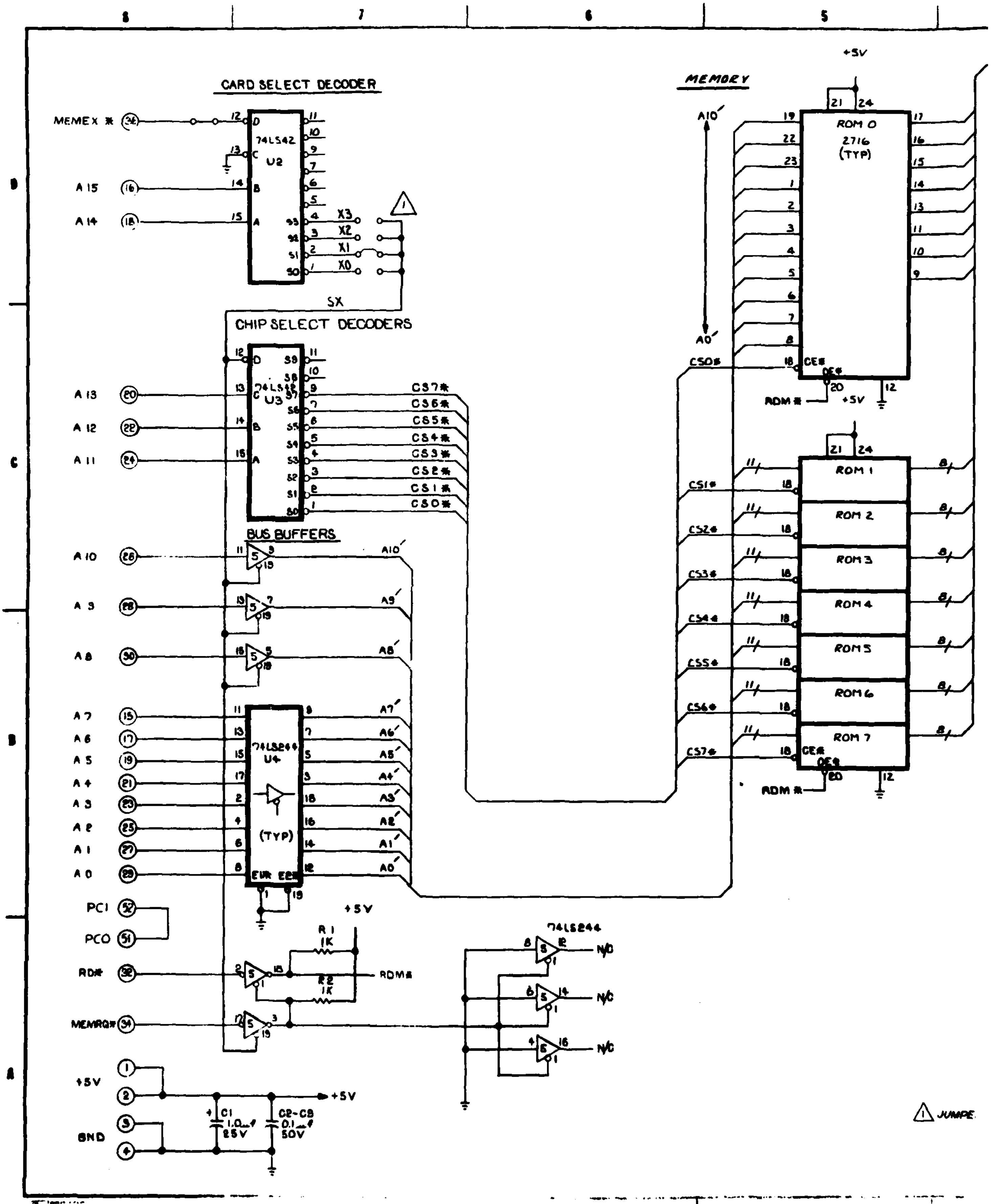
TEST NO.

PIX NO.

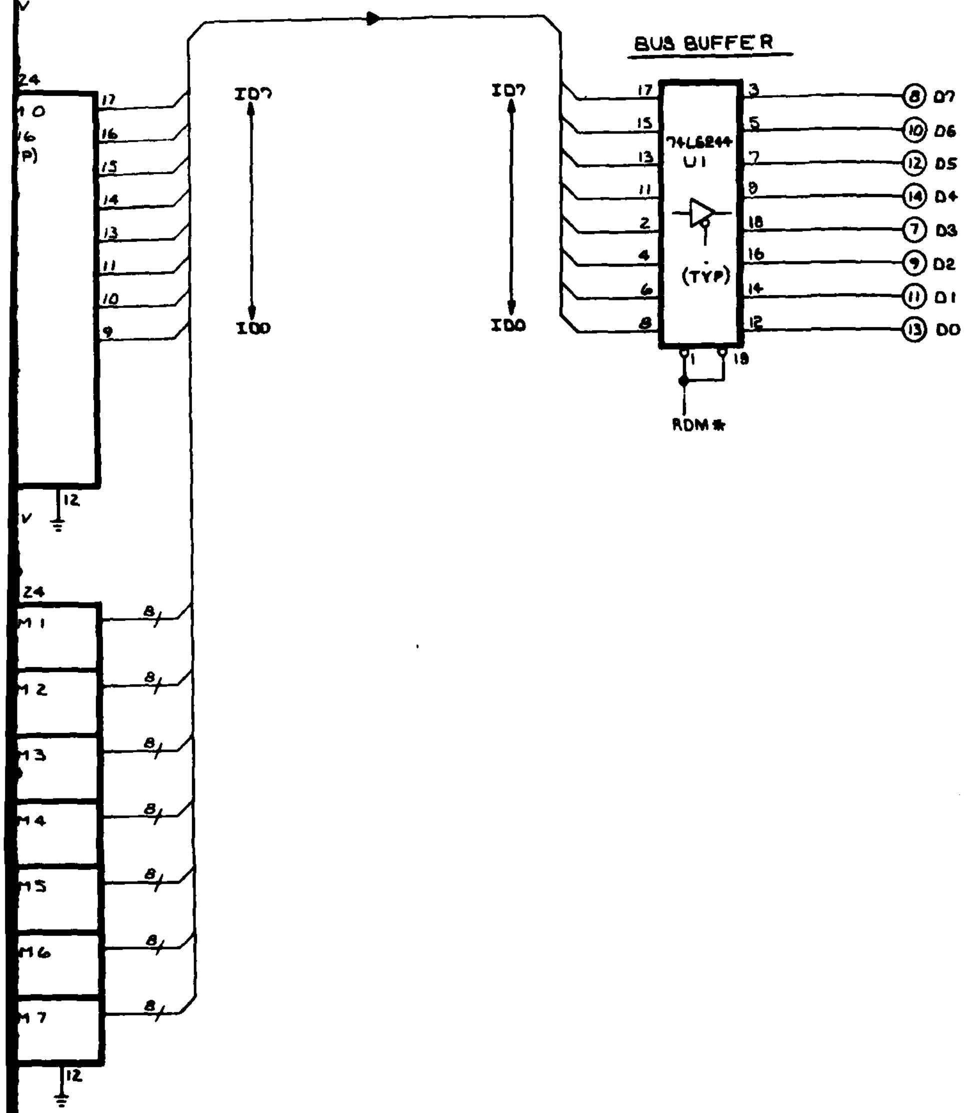
AD A145 531 PROGRESS IN POWER DISTRIBUTION IN FISCAL YEAR 1982(U) 3/4
GENERAL MOTORS CORP GOLETA CA DELCO ELECTRONICS DIV
OCT 82 R82-127

UNCLASSIFIED F/G 10/2 NL


1·0
2·5
2·2
2·0
1·1
1·8
1·25
1·4
1·6


CARD SELECT DECODER
CHIP SELECT DECODERS
BUS BUFFERS
MEMORY
74LS42
74LS244
ROM 0
2716
(TYP)
MEMEX *
A15
A14
A13
A12
A11
A10
A9
A8
A7
A6
A5
A4
A3
A2
A1
A0
PC1
PC0
RD#
MEMRQ#
+5V
GND
RDM#
R1 1K
R2 1K
C1 1.0µf 25V
C2-C8 0.1µf 50V
ROM 1
ROM 2
ROM 3
ROM 4
ROM 5
ROM 6
ROM 7
N/C
JUMPE

		REVISIONS		
REV	DOC REV	DESCRIPTION	DATE	APPR
	A	ADDED PINS 51 & 52. PCR.0261 & PCN.0129.	[illegible]	[illegible]
	B	ADDED JUMPER TO 2 & DELETED JUMPER FROM 1 OF U2. CHANGED NOTE 1. PCR.0326.	11-9-77	[illegible]
	C	REVISED PER PCN 0743	[illegible]	[illegible]
	D	REVISED PER PCN#0851	[illegible]	[illegible]



⚠1 JUMPER MOVES MEMORY IN 16K BLOCKS

ASSEMBLY 102714
PARTS LIST 102715

PRO-LOG CORPORATION

[redacted]

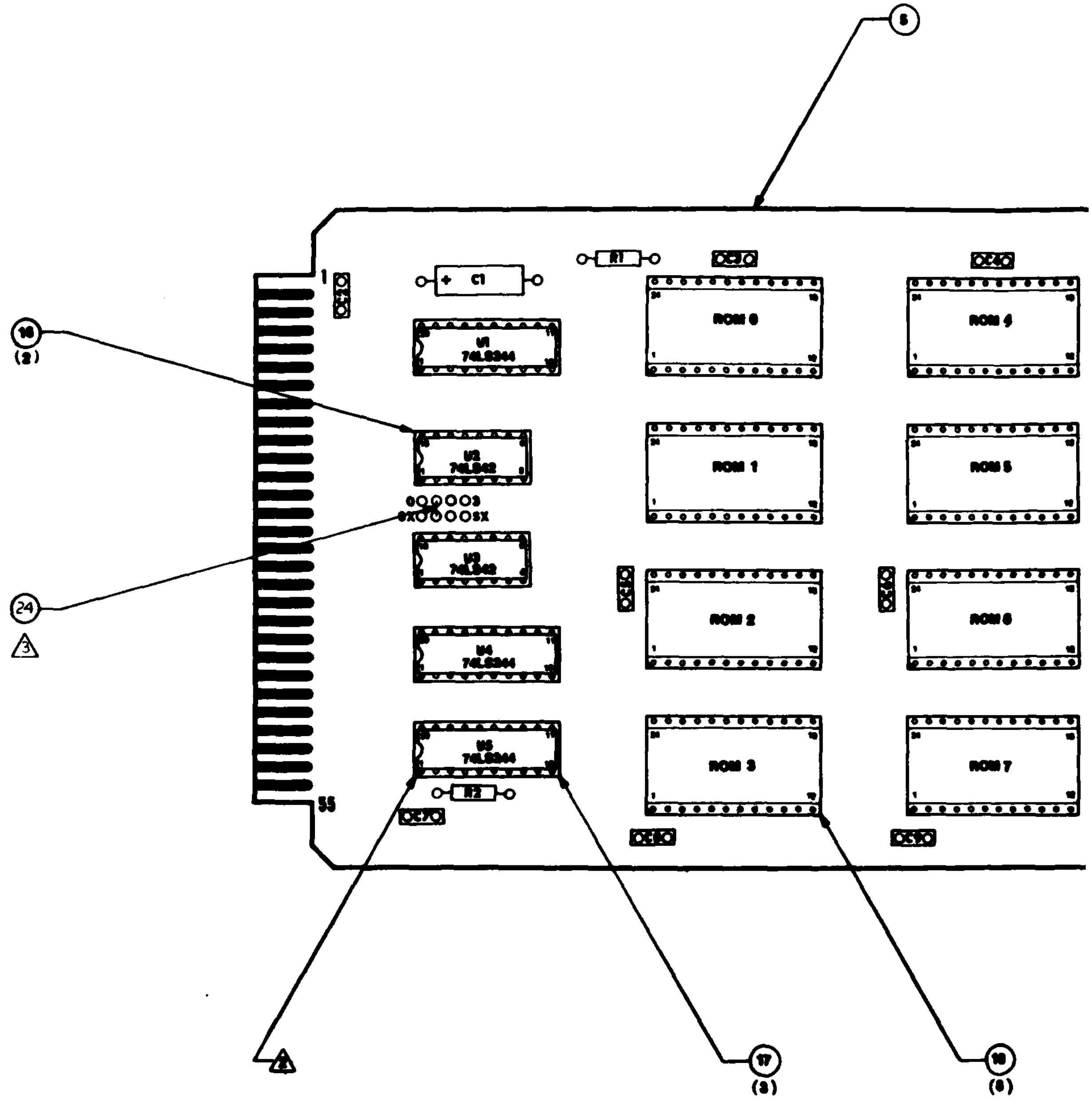
H. KEEVES 9-20-77

SCHEMATIC-7702
16K EPROM MEMORY
CARD

D 102713

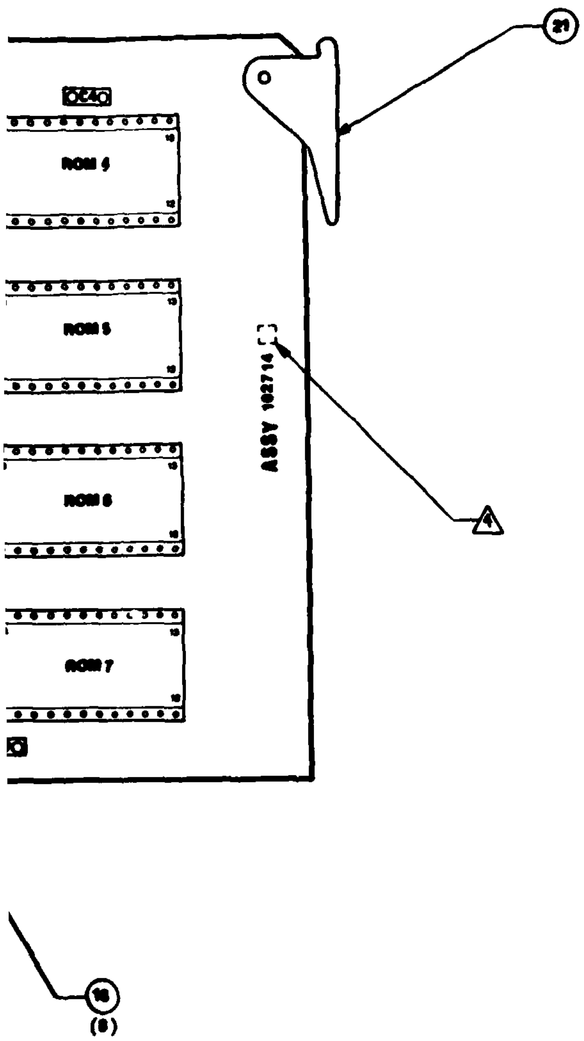
K-1

2



5. REF. DESIGNATIONS ARE FOR LOCATING PURPOSES ONLY AND MAY NOT APPEAR ON ACTUAL PART.
4 IDENTIFY WITH ASSEMBLY REV. LETTER USING RUBBER STAMP.
3 MAPPED AT 4000 - 7FFF.
2 -INDICATES PIN NO 1 OF SOCKETS (TYP).
1 FOR ASSY PROCEDURES SEE AS1004.
NOTES: UNLESS OTHERWISE SPECIFIED.

REVISIONS				
	A	ADDED ITEM 24. ADDED NOTE 3. PCR 0326.		
	B	REVISED PER PCN=0851		



SCHEMATIC NO. 102713
PARTS LIST NO. 102715

ITEM	DESCRIPTION	REF. DESIGNATION
10	1K, 1/4W, 5%	R1-R2
9		
8	0.1µf 50V	C2-C8
7	1.0µf 35V	C1

PRO-LOG CORPORATION

[redacted]

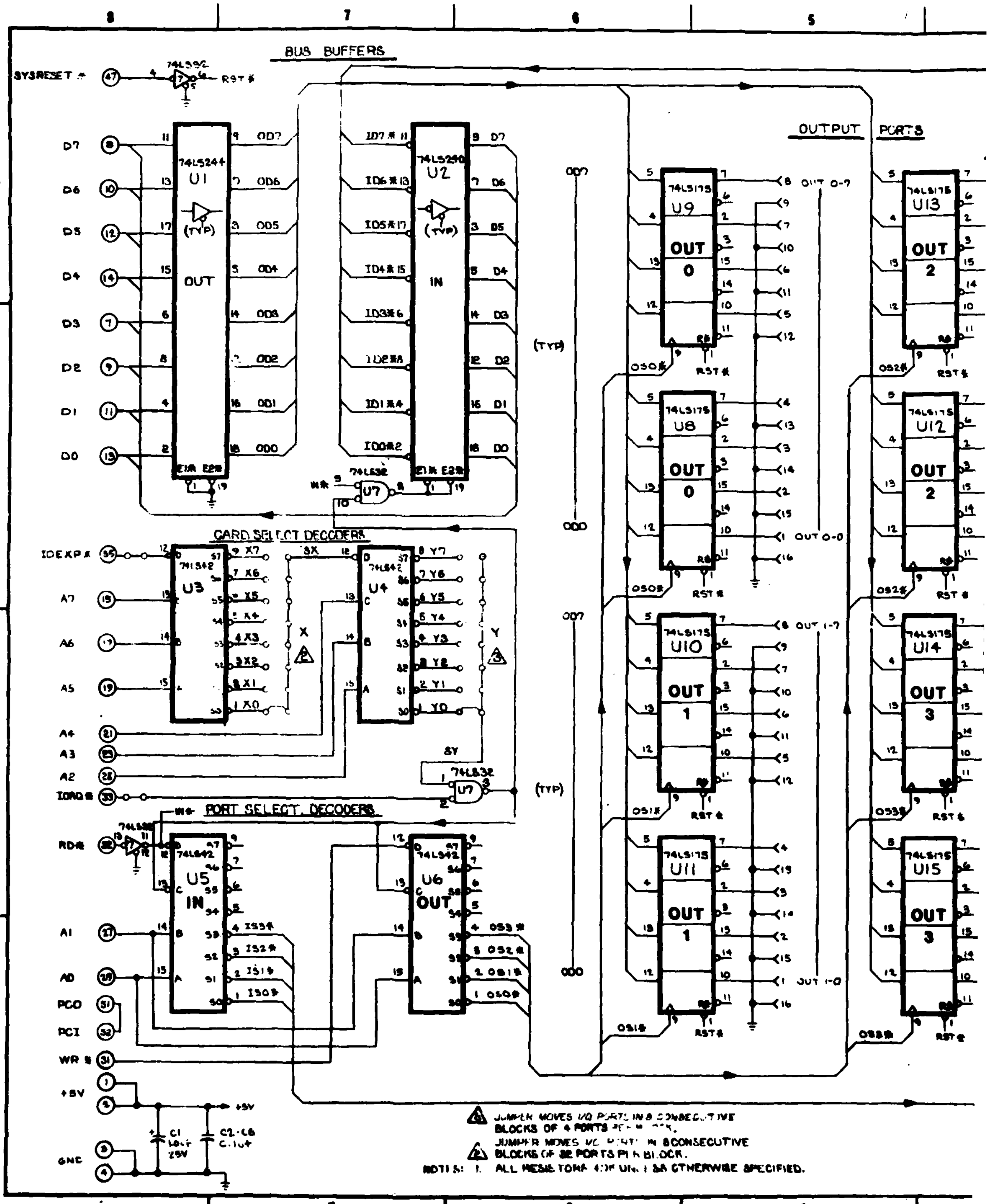
ASSEMBLY, 7702 16K EPROM MEMORY CARD.

C A CLARK 7-8-78

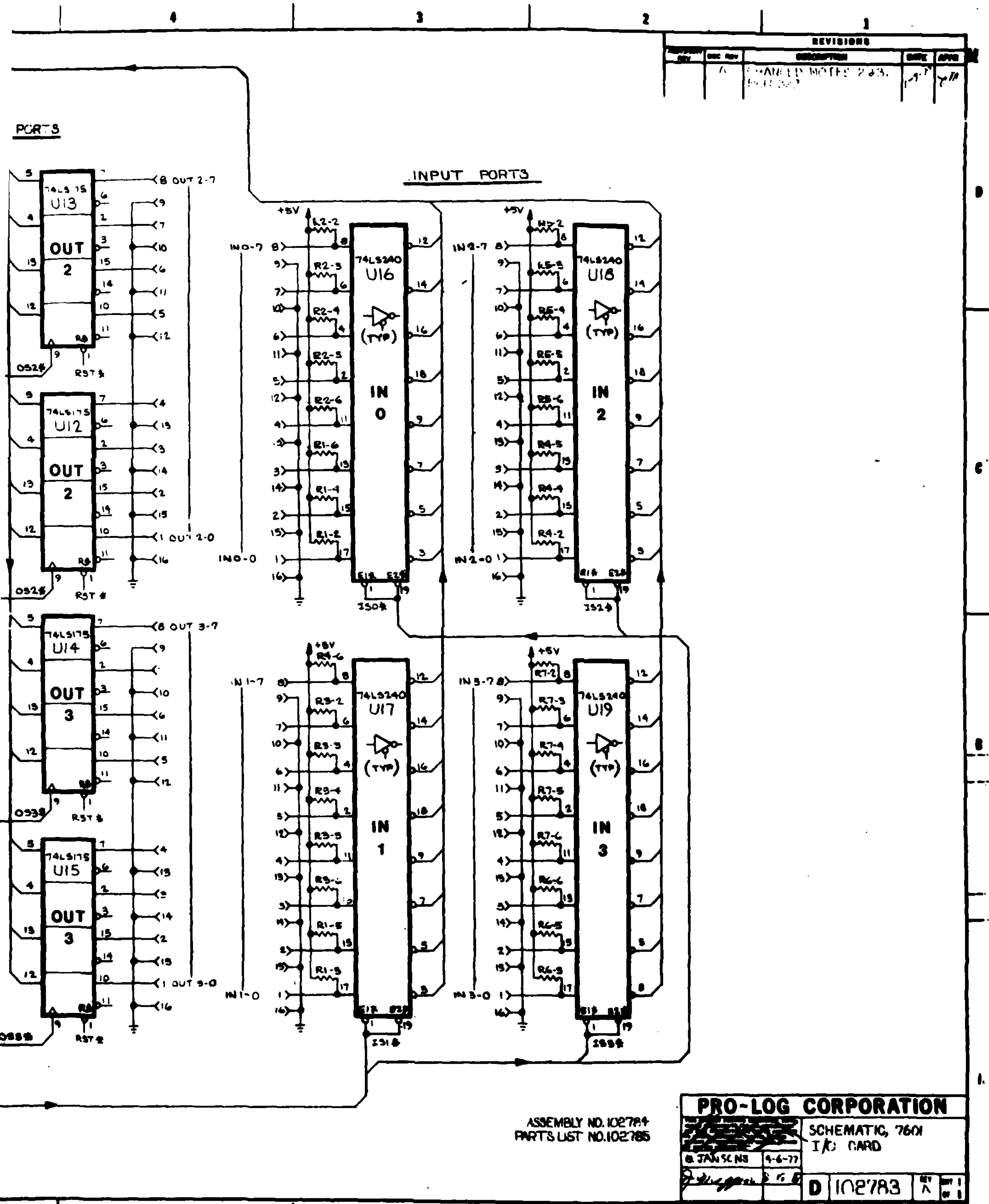
D 102714 REV B

K-2

2


BUS BUFFERS
SYSRESET #
74LS92
RST #
74LS244
U1
OUT
74LS240
U2
IN
CARD SELECT DECODERS
IDEXP #
74LS42
U3
U4
74LS32
U7
PORT SELECT DECODERS
U5
IN
U6
OUT
OUTPUT PORTS
74LS175
U9
OUT
0
U8
U10
U11
1
U13
2
U12
U14
3
U15
(TYP)
OUT 0-7
OUT 0-0
OUT 1-7
OUT 1-0
D7
D6
D5
D4
D3
D2
D1
D0
A7
A6
A5
A4
A3
A2
IORQ #
RD #
A1
A0
PC0
PC1
WR #
+5V
GND
C1
C2-C6
NOTES: 1. ALL RESISTORS 4.7K UNLESS OTHERWISE SPECIFIED.

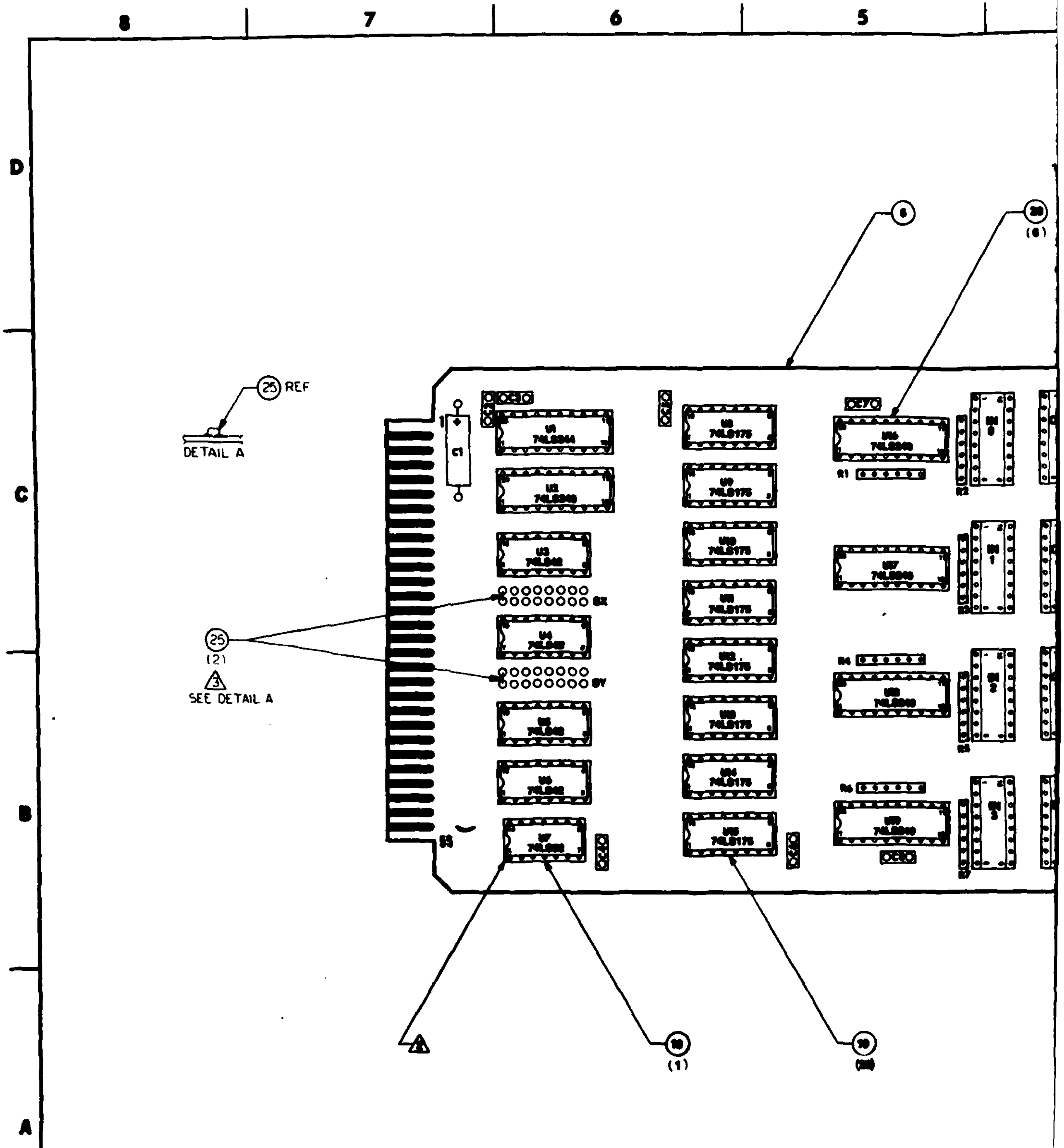
R82-127



REVISIONS
PORTS
INPUT PORTS
74LS175 U13 OUT 2
74LS175 U12 OUT 2
74LS175 U14 OUT 3
74LS175 U15 OUT 3
74LS240 U16 IN 0
74LS240 U18 IN 2
74LS240 U17 IN 1
74LS240 U19 IN 3
(TYP)
+5V
8 OUT 2-7
1 OUT 2-0
8 OUT 3-7
1 OUT 3-0
IN0-7
IN0-0
IN2-7
IN2-0
IN1-7
IN1-0
IN3-7
IN3-0
RST
ASSEMBLY NO. 102784
PARTS LIST NO. 102785
PRO-LOG CORPORATION
SCHEMATIC, 7601 I/O CARD
4-6-77
D 102783

K-3

2

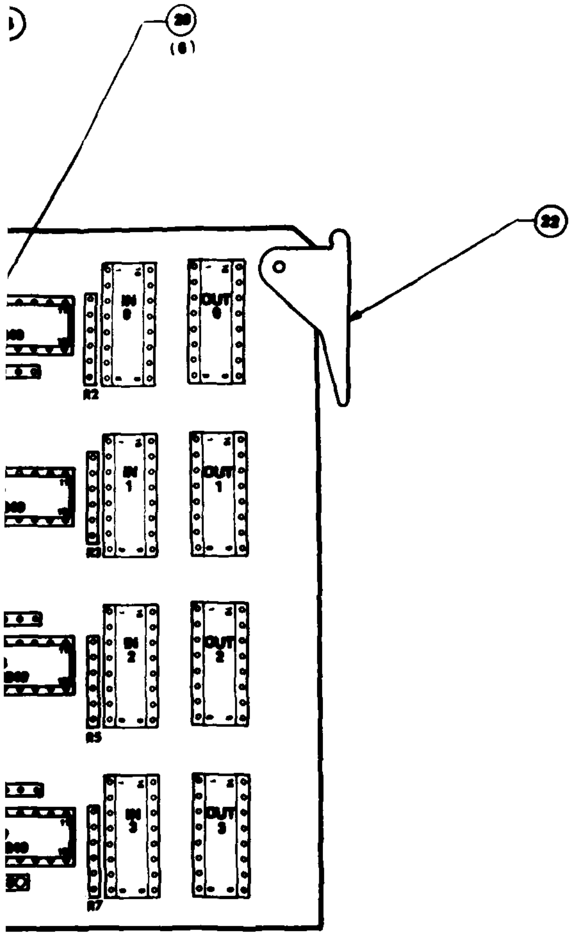


3 MAPPED TO PORT (X).
2 INDICATES PIN NO.1 OF SOCKETS (TYP).
1. FOR ASSY. PROCEDURES SEE AS1004.
NOTES: UNLESS OTHERWISE SPECIFIED

101356 8 7 6 5

R82-127

REVISIONS				
REV	ECO REV	DESCRIPTION	DATE	APPR
	A	ADDED ITEM 25. ADDED NOTE 4, PCR 329	1 7 77	gm



SCHEMATIC NO. 102783
PARTS LIST NO. 102785

ITEM	DESCRIPTION	REF. DESIGNATION
10	47K NETWORK	R1 - R7
9		
8	0.1 µf 50V	C2 - C8
7	1.0 µf 25V	C1

PRO-LOG CORPORATION

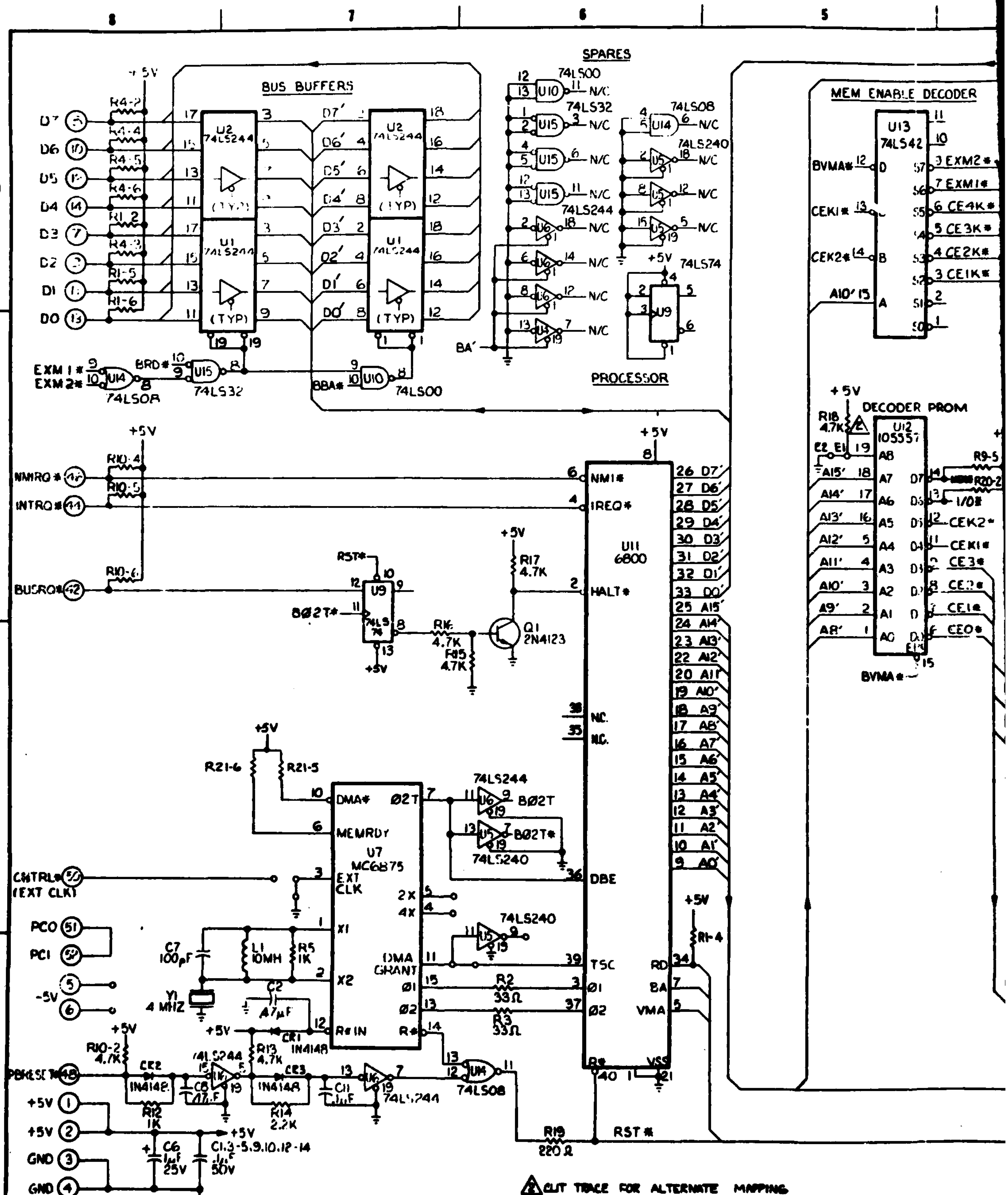
ASSEMBLY, 7601 I/O CARD

C A CLARK 8-12-76

D 102784 REV A SHT 1 OF 1

K-4

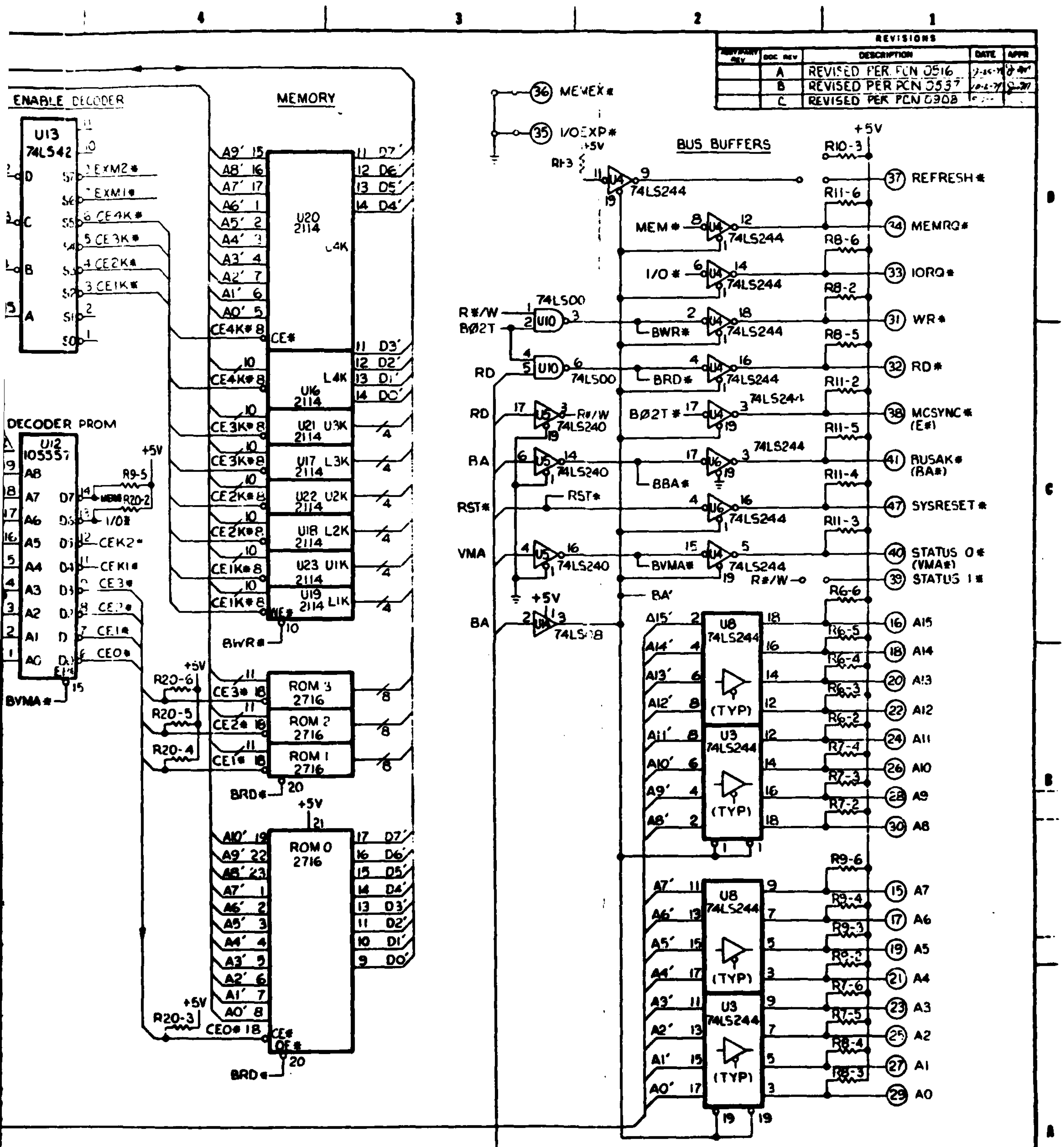
2



⚠ CUT TRACE FOR ALTERNATE MAPPING

NOTES: 1. ALL RESISTORS ARE 4.7K UNLESS OTHERWISE SPECIFIED.

R82-127



		REVISIONS		
	A	REVISED PER PCN 0516		
	B	REVISED PER PCN 0537		
	C	REVISED PER PCN 0908		

ECIFIED.

ASSEMBLY 104912
PART LIST 104913

PRO-LOG CORPORATION

[redacted]

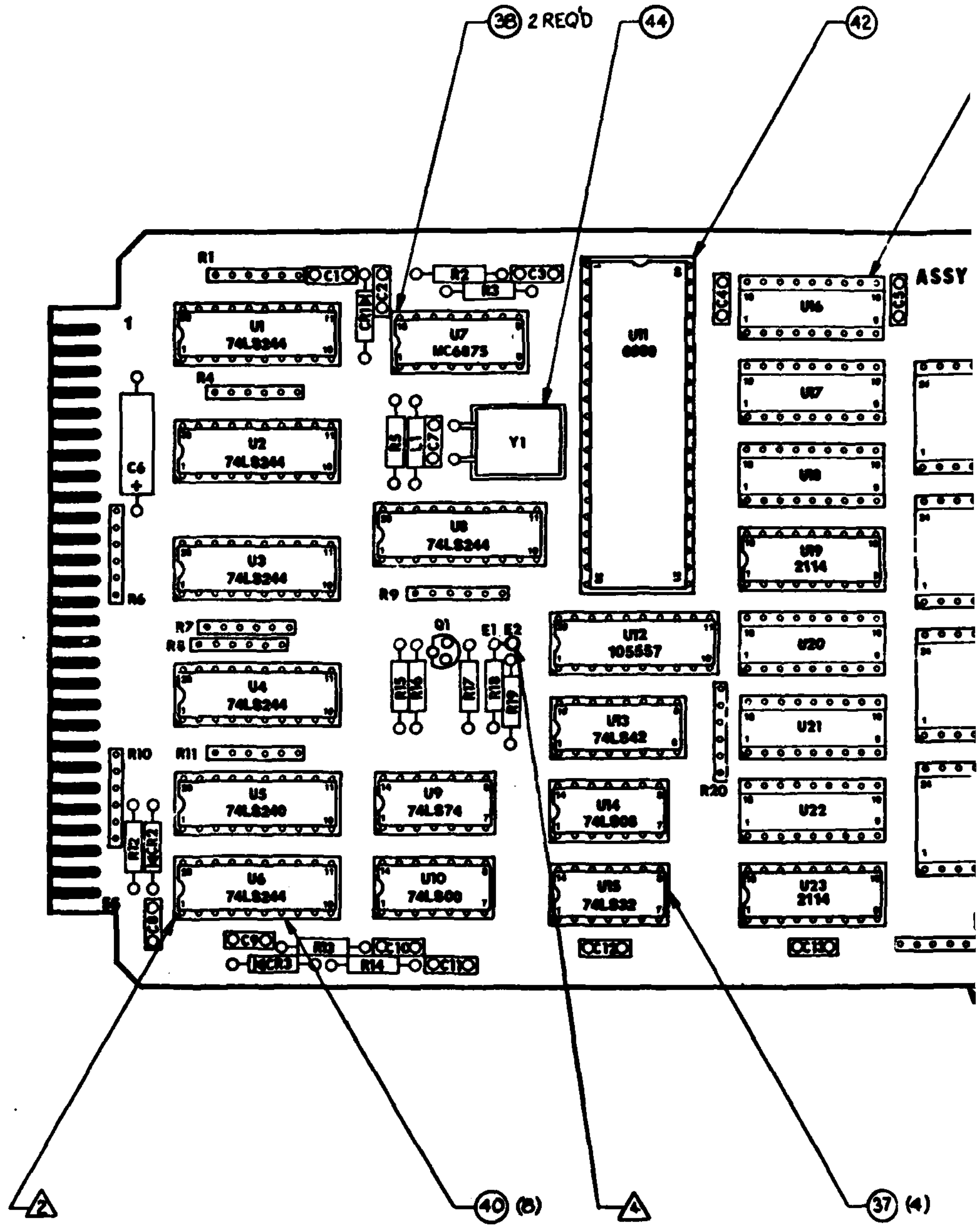
SAL MARULLO 10-10-78
GENE PAPPE

SCHEMATIC, 7802 PROCESSOR CARD 6800 CPU

D 10491

K-5

2



4 CUT TRACE FOR ALTERNATE MAPPING

3 IDENTIFY WITH ASSY REV LETTER USING RUBBER STAMP

2 INDICATES PIN NO. 1 OF SOCKETS (TYP).

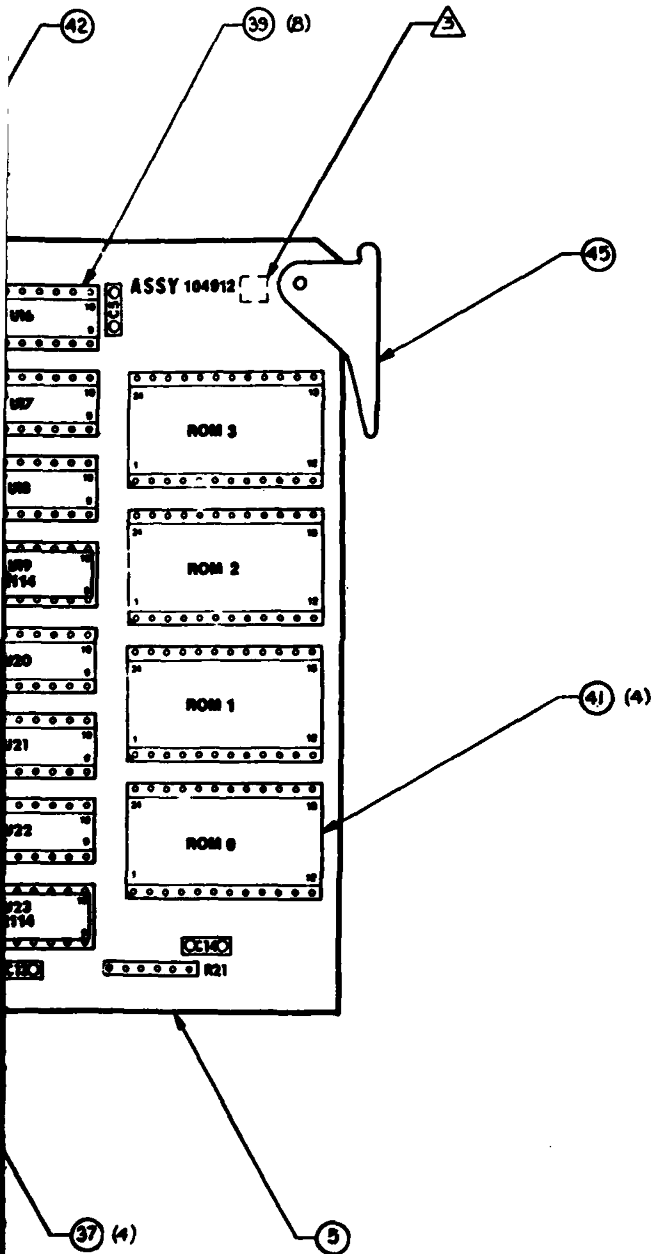
1. FOR ASSY PROCEDURES SEE AS1004.

NOTES: UNLESS OTHERWISE SPECIFIED.

R82-127

7 6 5

REVISIONS				
REV/PART REV	DOC REV	DESCRIPTION	DATE	APPR
	A	REVISED PER PCN 0516	9-26	
	B	REVISED PER PCN	12-2-7	
	C	REVISED PER PCN 0478	10-2-7	
	D	REVISED PER PCN 0908		



ITEM	DESCRIPTION	REF. DESIGNATION
36	2.2K 1/4W,CF,5%	R14
35	1K 1/4W,CF,5%	R5.12
34	33Ω 1/4W,CF,5%	R2,3
33	4.7K 1/4W,CF,5%	R13,15-18
32	220Ω 1/4W,CF,5%	R19
31	4.7K, NETWORK	R1.4.6-11.20.21
14	10μH 10%	L1
13	2N4123	Q1
12	1N4148	CR1-3
11	4MHZ	Y1
10	1.0μf, 50V	C6
9	.47μf, 50V	C2.8
8	.1μf, 50V	C1.3-5.9-14
7	100pf, 50V	C7

SCHEMATIC 104911
PART LIST 104913

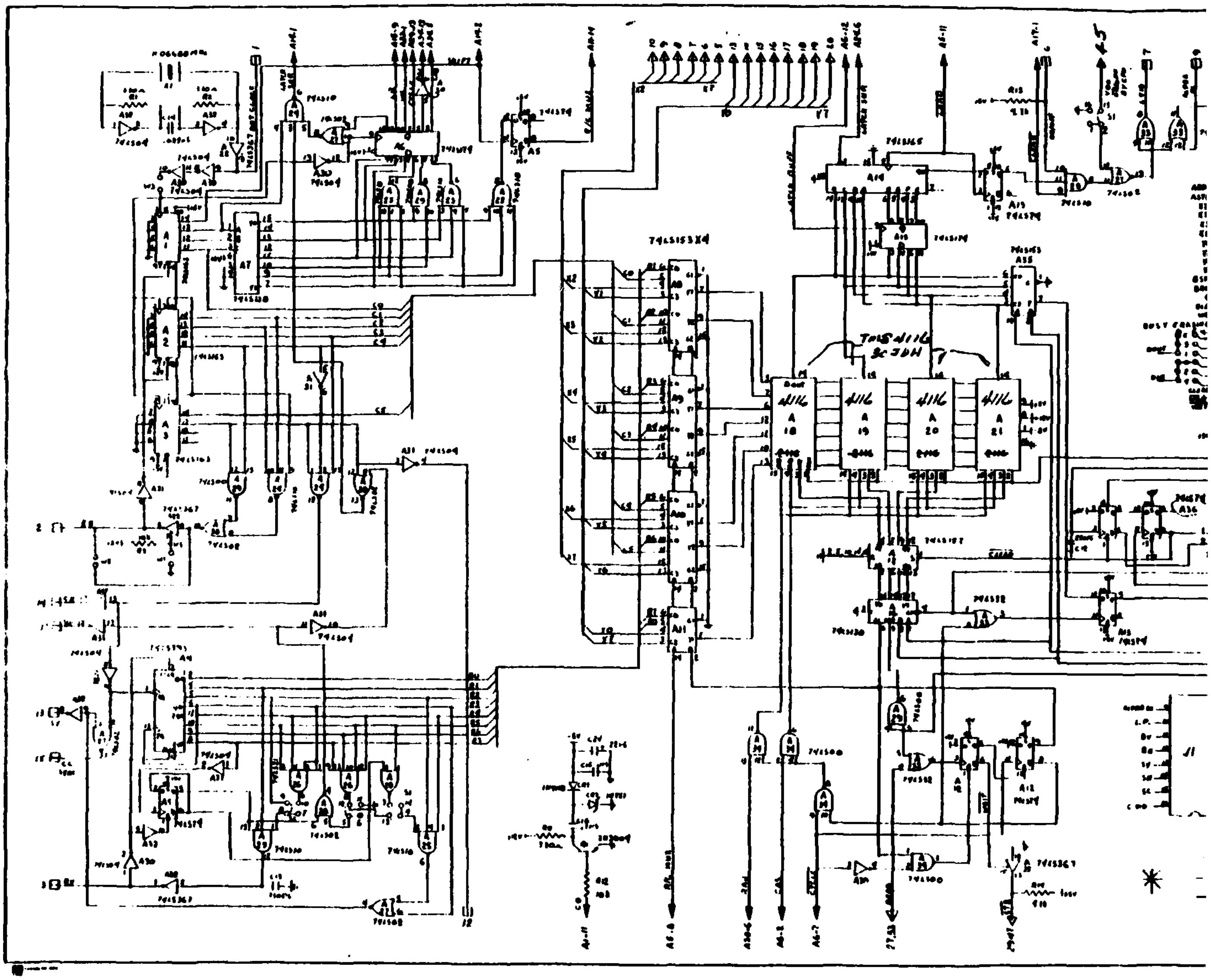
PRO-LOG CORPORATION

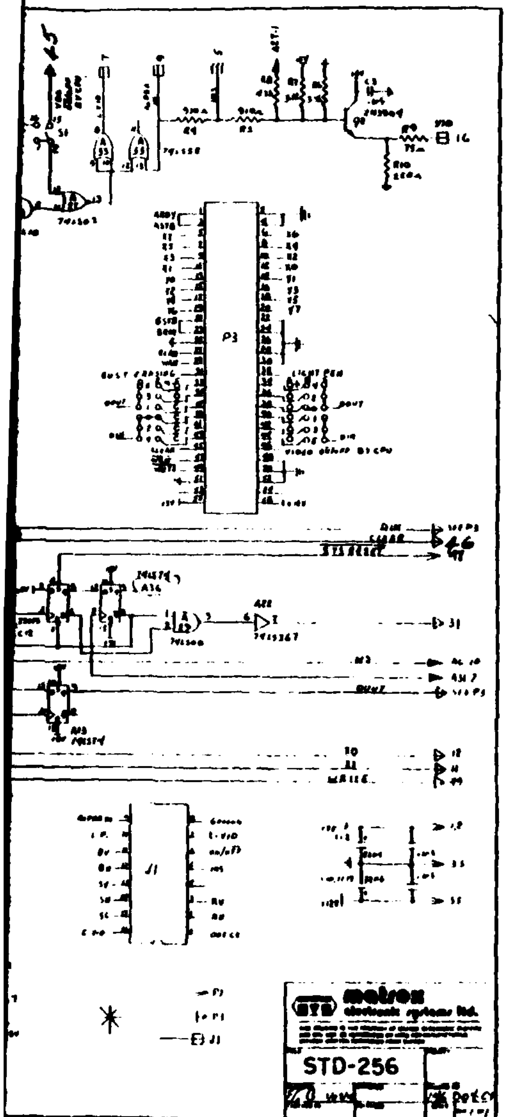
GENE PAPPE 1-26-75

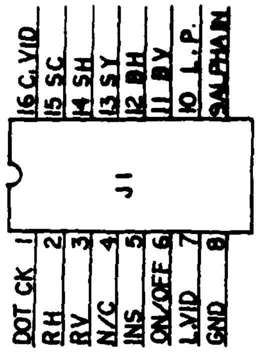
ASSEMBLY, 7802
PROCESSOR CARD
6800 CPU

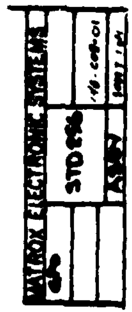
D 104912 REV D SHT 1 OF 1

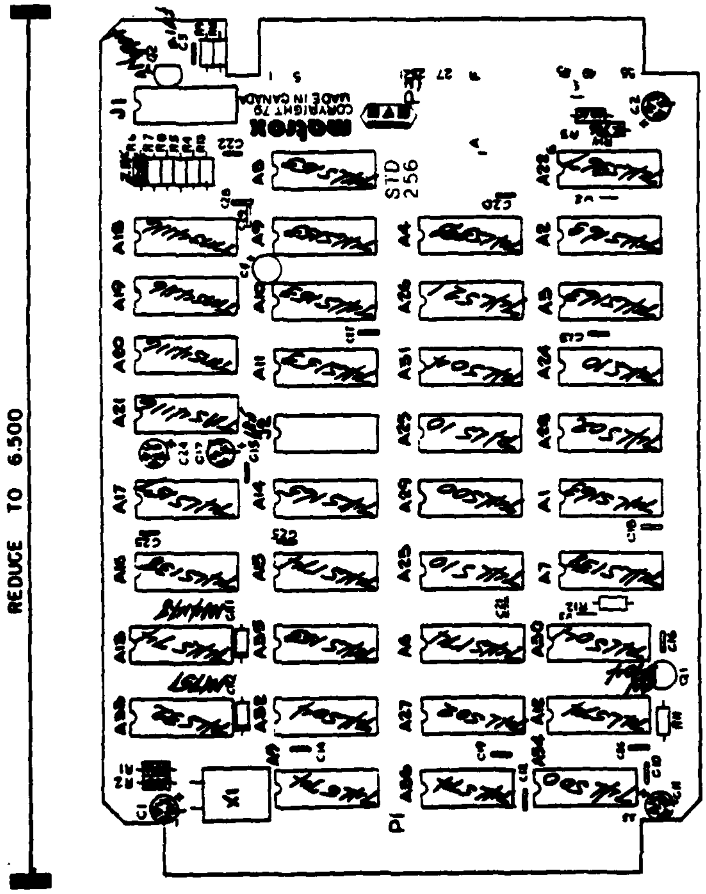
2 4 3 2 1 K-6


74LS153X4
TMS4116
4116
4116
4116
4116


P3
J1
matrox electronic systems ltd.
STD-256

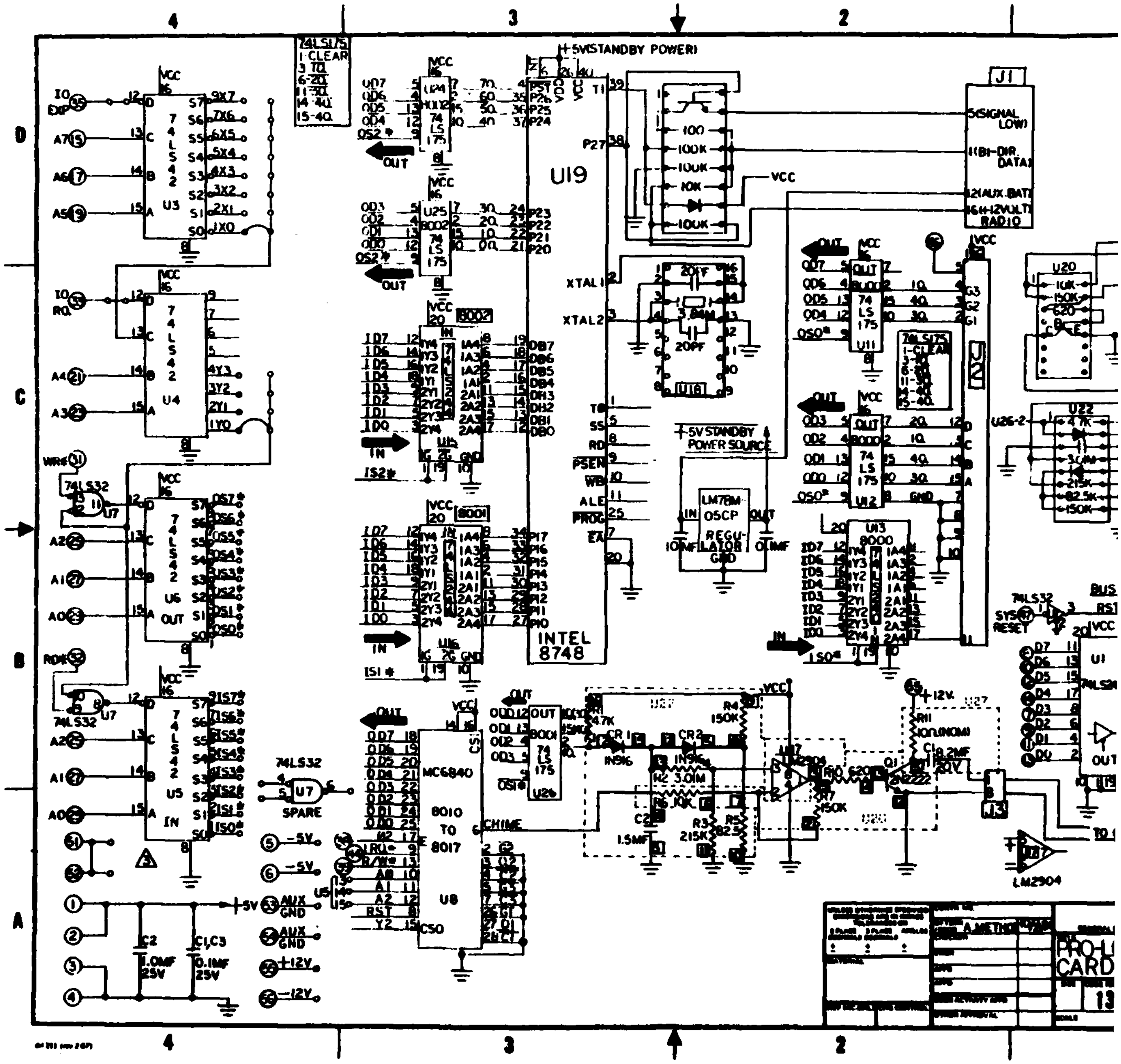

16 C.VID
15 SC
14 SH
13 SY
12 BH
11 BV
10 L.P.
9 ALPHAN
J1
DOT CK 1
RH 2
RV 3
N/C 4
INS 5
ON/OFF 6
L.VID 7
GND 8


MATROX ELECTRONIC SYSTEMS
STD 256
ASSY


REDUCE TO 6.500
J1
P1
STD 256
matrox
COPYRIGHT 79
MADE IN CANADA

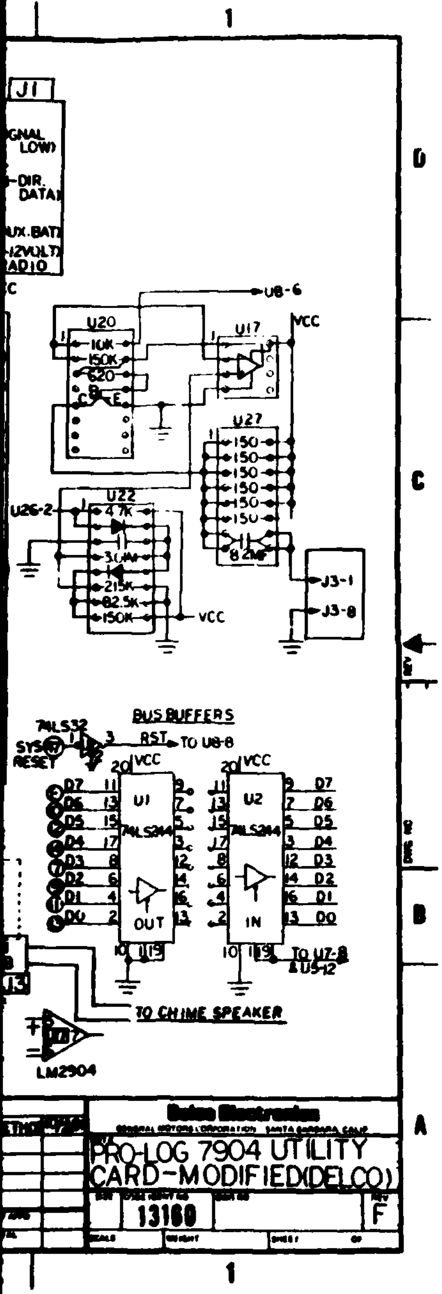
K-7/8

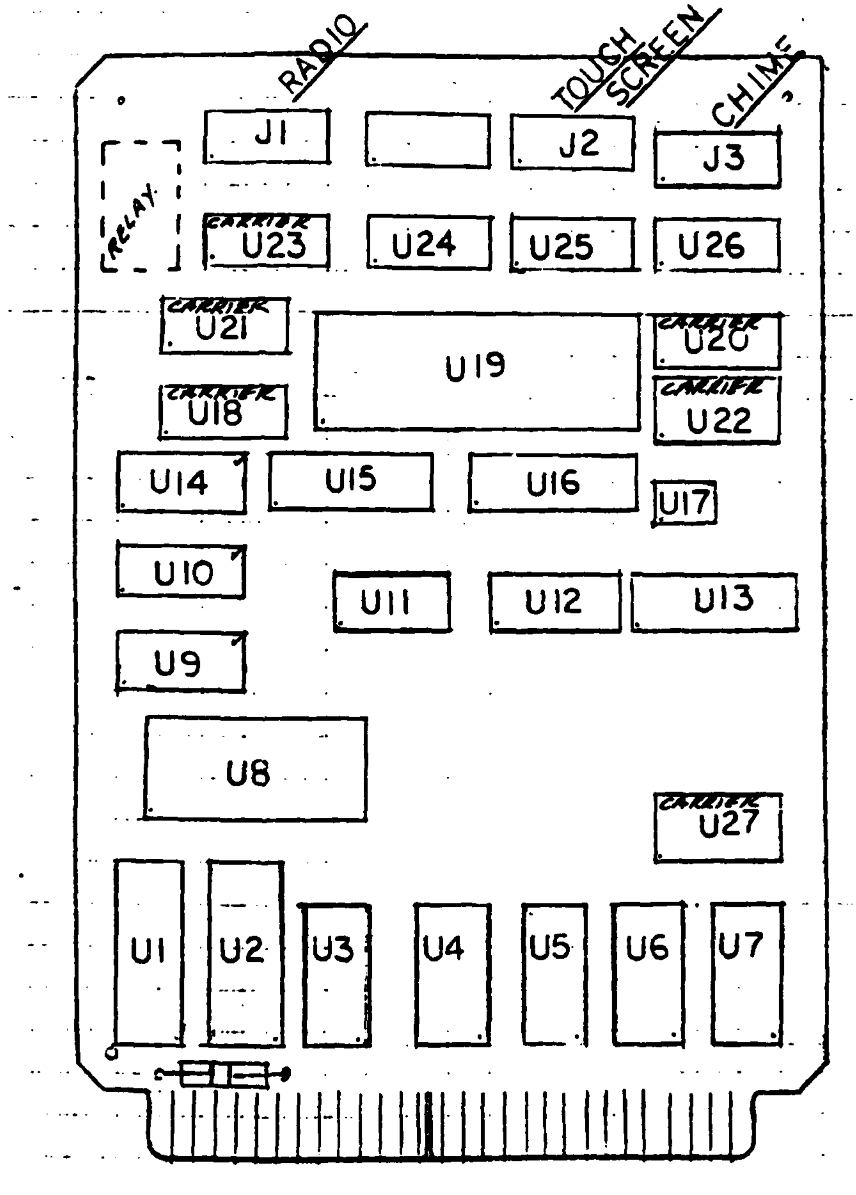
2



4
3
2
D
C
B
A
+5V(STANDBY POWER)
74LS175
1-CLEAR
U3
U4
U5
U6
U7
74LS32
SPARE
U19
INTEL
8748
XTAL 1
XTAL 2
U18
20PF
+5V STANDBY
POWER SOURCE
LM78M-
05CP
REGU-
LATOR
GND
OUT
IN
VCC
J1
SIGNAL
LOW
BI-DIR.
DATA
AUX.BAT
+12VOLT
RADIO
U11
U12
U13
U20
U21
U22
U24
U25
U26
U27
MC6840
8010
TO
8017
U8
CHIME
SYSTEM
RESET
LM2904
IN916
2N2222
J3
+5V
-5V
+12V
-12V
AUX
GND

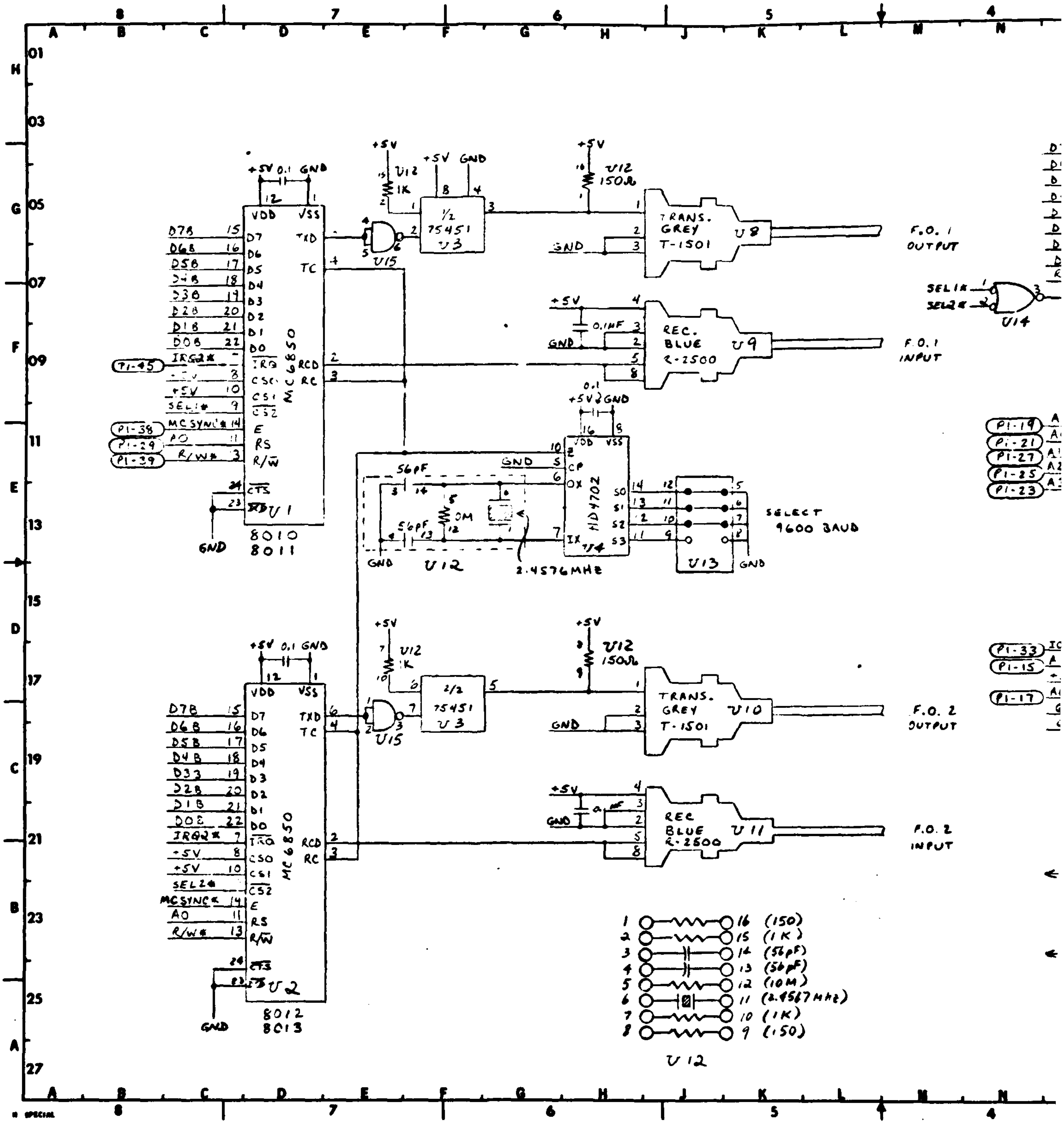
R82-127


J1
U20
U17
U27
U22
VCC
U8-6
U26-2
J3-1
J3-8
BUS BUFFERS
74LS32
SYS RESET
RST
TO U8-8
U1
U2
74LS244
OUT
IN
TO U7-8 & U5-12
TO CHIME SPEAKER
LM2904
Delco Electronics
PRO-LOG 7904 UTILITY CARD-MODIFIED(DELCO)
13160
F

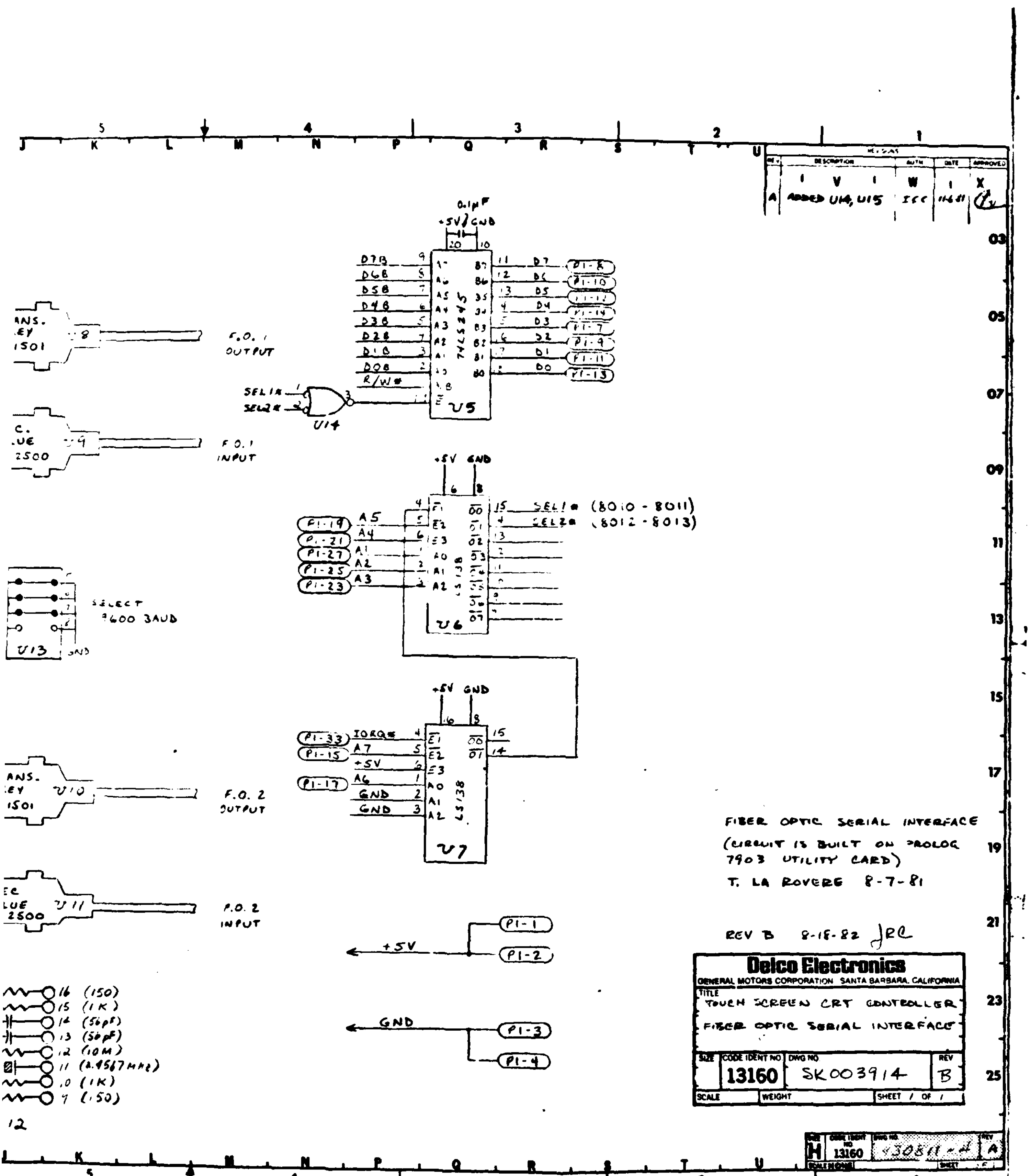

RADIO
TOUCH SCREEN
CHIME
J1
J2
J3
RELAY
CARRIER U23
U24
U25
U26
CARRIER U21
U19
CARRIER U20
CARRIER U18
CARRIER U22
U14
U15
U16
U17
U10
U11
U12
U13
U9
U8
CARRIER U27
U1
U2
U3
U4
U5
U6
U7

K-9/10

2



MC6850
8010
8011
8012
8013
U1
U2
V3
U8
U9
U10
U11
U12
U13
U14
U15
75451
TRANS.
GREY
T-1501
REC.
BLUE
R-2500
F.O. 1 OUTPUT
F.O. 1 INPUT
F.O. 2 OUTPUT
F.O. 2 INPUT
HD4702
SELECT 9600 BAUD
2.4576MHZ
GND
+5V
1 (150)
2 (1K)
3 (56pF)
4 (56pF)
5 (10M)
6 (2.4567MHz)
7 (1K)
8 (150)



ADDED U14, U15
0.1µF
+5V GND
74LS245
U5
U14
SEL1# (8010 - 8011)
SEL2# (8012 - 8013)
LS138
U6
U7
F.O. 1 OUTPUT
F.O. 1 INPUT
F.O. 2 OUTPUT
F.O. 2 INPUT
SELECT 9600 BAUD
U13
U10
U11
+5V
GND
FIBER OPTIC SERIAL INTERFACE
(CIRCUIT IS BUILT ON PROLOG 7903 UTILITY CARD)
T. LA ROVERE 8-7-81
REV B 8-18-82 JRC
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA
TOUCH SCREEN CRT CONTROLLER
FIBER OPTIC SERIAL INTERFACE
13160
SK003914
B
SHEET 1 OF 1

K-11

2

APRIL 10, 1981

PRELIMINARY

MODEL SPECIFICATIONS FOR

VEHICULAR CRT MONITOR

MODEL VM34H

ZENITH RADIO CORPORATION

VEHICULAR & INDUSTRIAL ELECTRONIC PRODUCTS

PO

CATHODE RAY TUBE

3" x 4" aspect ratio, 12KV nominal high voltage at 50μA average beam current.

DISPLAY AREA

12 square inches, defined by 3" x 4" rectangle centered on the CRT faceplate.

IN

OPTICAL CHARACTERISTICS

Brightness (Note 1)	2000 Foot Lamberts
Color	Yellow-Green
Faceplate Transmission	65%
Faceplate Reflectivity	36% Typical
Contrast Ratio (Zero Ambient Illumination)	35:1 Min.
Viewing Angle	To limit of character recognition (without reticules or decals).
Center Spot Size (Beam Current 1.5ma)	.037 ± .005 inches
Resolution	Pulse rise time 70 n.s. for 50 volt rise at CRT cathode.
Ageing Characteristic (Note 2)	10,000 hours to 50% of original brightness

Ho

MONITOR CHASSIS ELECTRICAL DATA

POWER SUPPLY

Input Voltage Range..................................	9 to 24 Volts
Input Current..	1.8 Amps ±15% Input Voltage = 12 Volts
Regulator System.....................................	Switch-mode

System Protection:

Undamaged When Subjected To:

Jumper Starts................................	+24V for 30 minutes
Reverse Polarity.............................	-24V
Load Dump....................................	120V, 188ms Time Constant
Inductive Load Switching.....................	-286V, 1ms Time Constant
Alternator Field Decay.......................	-90V, 38ms Time Constant
Mutual Coupling..............................	214V, 1 μs Time Constant

INPUTS (Refer to Figure 1)

Video:

Input Level..................................	1 to 5 Volts peak-to-peak
Input Impedance..............................	100 ohm
Coupling.....................................	DC
Polarity.....................................	Increasing voltage at input increases CRT brightness: black is at zero volts.

Horizontal Drive (Refer to Figure 1):

Input Level..................................	4-12V p-p Positive Edge Triggered
Frequency....................................	15,750 ± 300 Hz
Waveshape....................................	Rectangular
Minimum Pulse Width..........................	1 μs
Input Impedance..............................	1K ohm

s.
RT
s

2

K-12a

MONITOR CHASSIS ELECTRICAL DATA (cont'd.)

Vertical Sync (Refer to Figure 1):

Input Level..	2 to 5 Volts peak-to-peak
Frequency Range....................................	85 to 115 Hz.
Waveshape..	Positive-going Rectangular Pulse
Pulse Width..	50 to 2500 μsec.
Input Impedance....................................	6.8K ohm

CONTROLS

Automatic Brightness Set

Brightness Range

Background

Focus

Vertical Size

Horizontal Size

Raster Centering (adjustment rings on yoke)

MONITOR CHASSIS ELECTRICAL DATA

ENVIRONMENTAL CHARACTERISTICS:

Temperature:	Operational..............................	-40°C to +85°C
	Storage..................................	-40°C to +85°C
Humidity:	Operational..............................	0 - 98% at 38°C

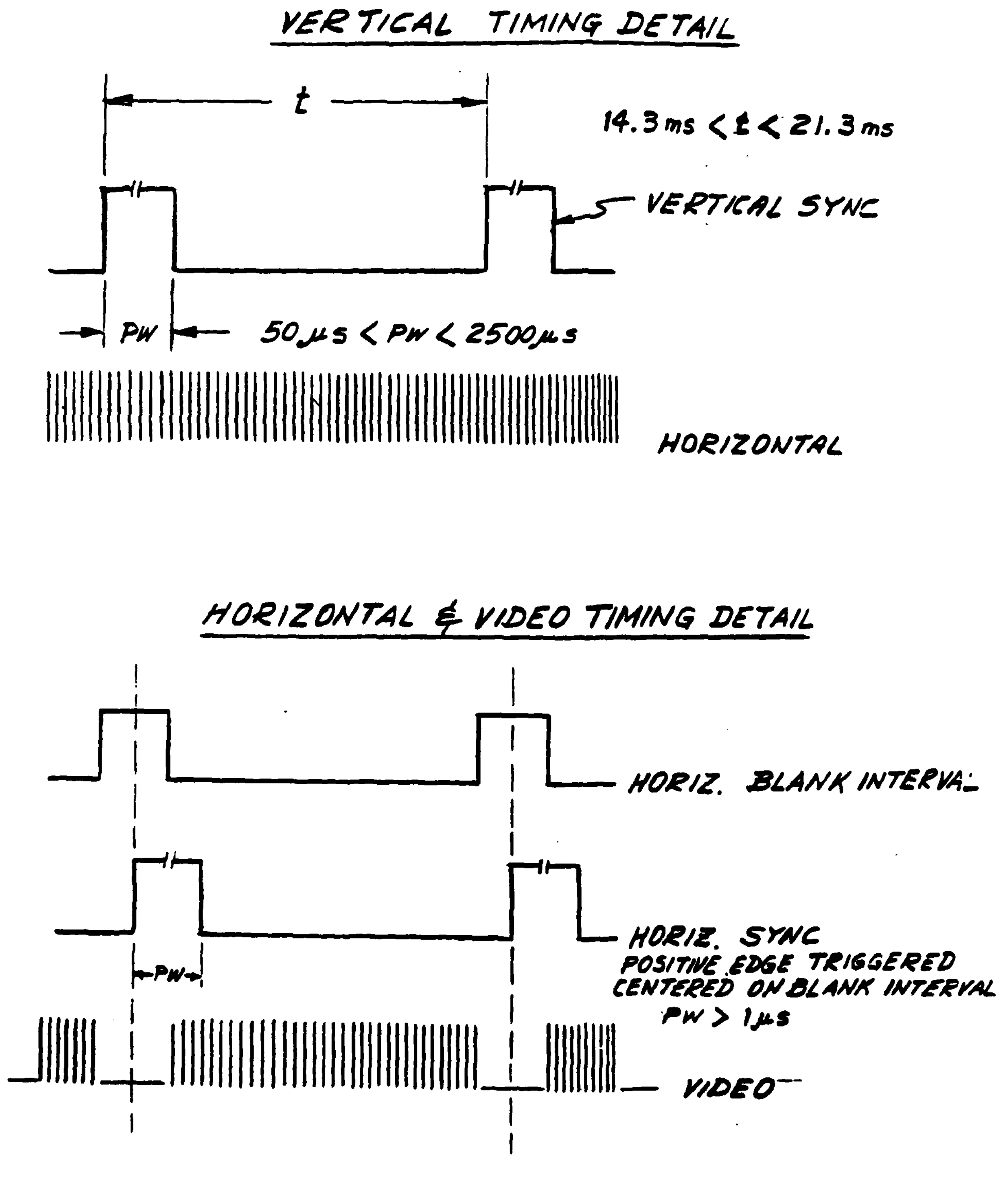

VERTICAL TIMING DETAIL
t
14.3 ms < t < 21.3 ms
VERTICAL SYNC
PW
50 µs < PW < 2500 µs
HORIZONTAL
HORIZONTAL & VIDEO TIMING DETAIL
HORIZ. BLANK INTERVAL
HORIZ. SYNC
POSITIVE EDGE TRIGGERED
CENTERED ON BLANK INTERVAL
PW > 1 µs
PW
VIDEO

FIG. 1

K-12b.

2

MONITOR CHASSIS ELECTRICAL DATA (cont'd.)

VIBRATION

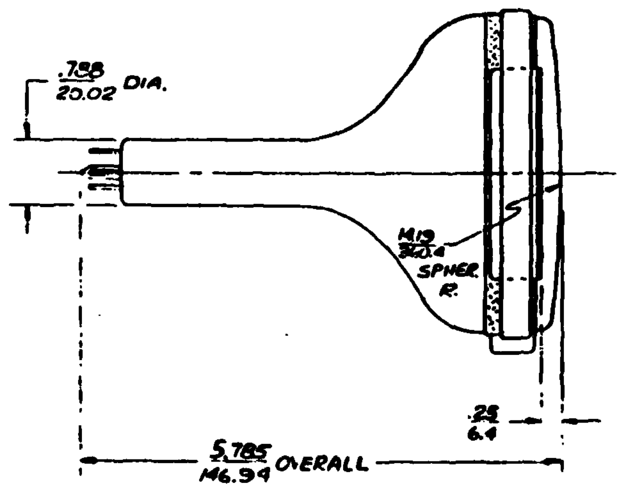
Operational Storage	1.3 g maximum 1.0 to 5.0 Hertz 6 g maximum 5 - 1000 Hertz Sinusoidal

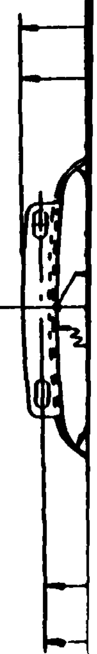
SHOCK

Operational Storage	50 g; 1/2 sine 9-13 millisec. duration

ALTITUDE

Operational Storage	15,000 ft. Maximum



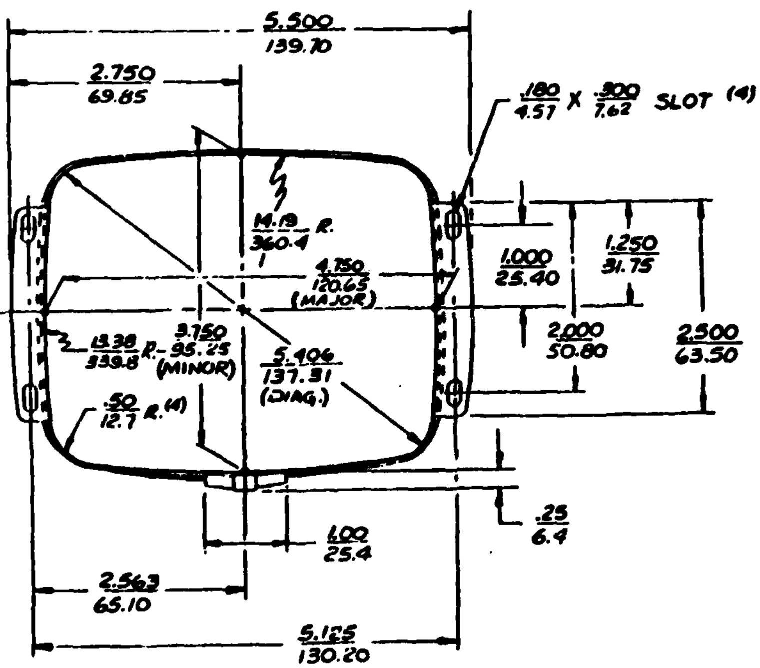


NOTE: MILLIMETER VALUE SHOWN BELOW INCH DIMENSION; i.e., 1.00 IN. / 25.4 MM

NOTE 1: Brightness is measured by producing an unmodulated (DC) raster in the central 3"x4" area of the faceplate. The brightness is adjusted to produce 1mA average beam current. The brightness is then measured such that the measurement area fills the field of view of the measuring instrument. Ambient illumination is zero. The standard eye response curve (4000Å - 7800Å) should be used.

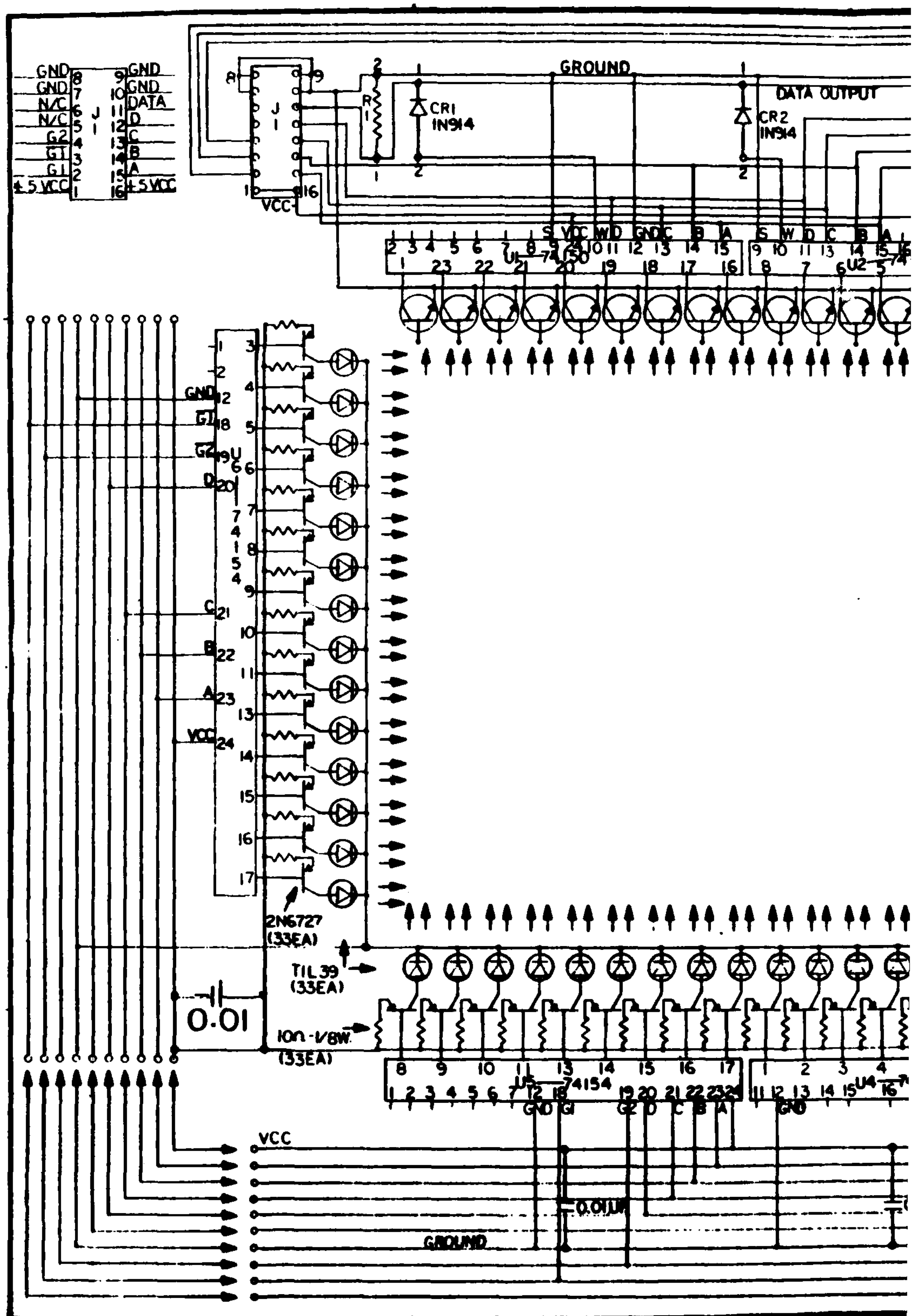
NOTE 2: The ageing characteristic defines the time interval over which the light output of the tube is reduced to 50% of its original value. The usage schedule used to derive the ageing characteristic is shown below. This schedule defines the time that the VCRT spends at a given output level.

USE TIME (Percent)	RELATIVE BRIGHTNESS (Percent)	ABSOLUTE BRIGHTNESS (Foot Lamberts)
10	100	2000
20	75	1500
25	50	1000
20	30	600
15	20	400
10	10	200

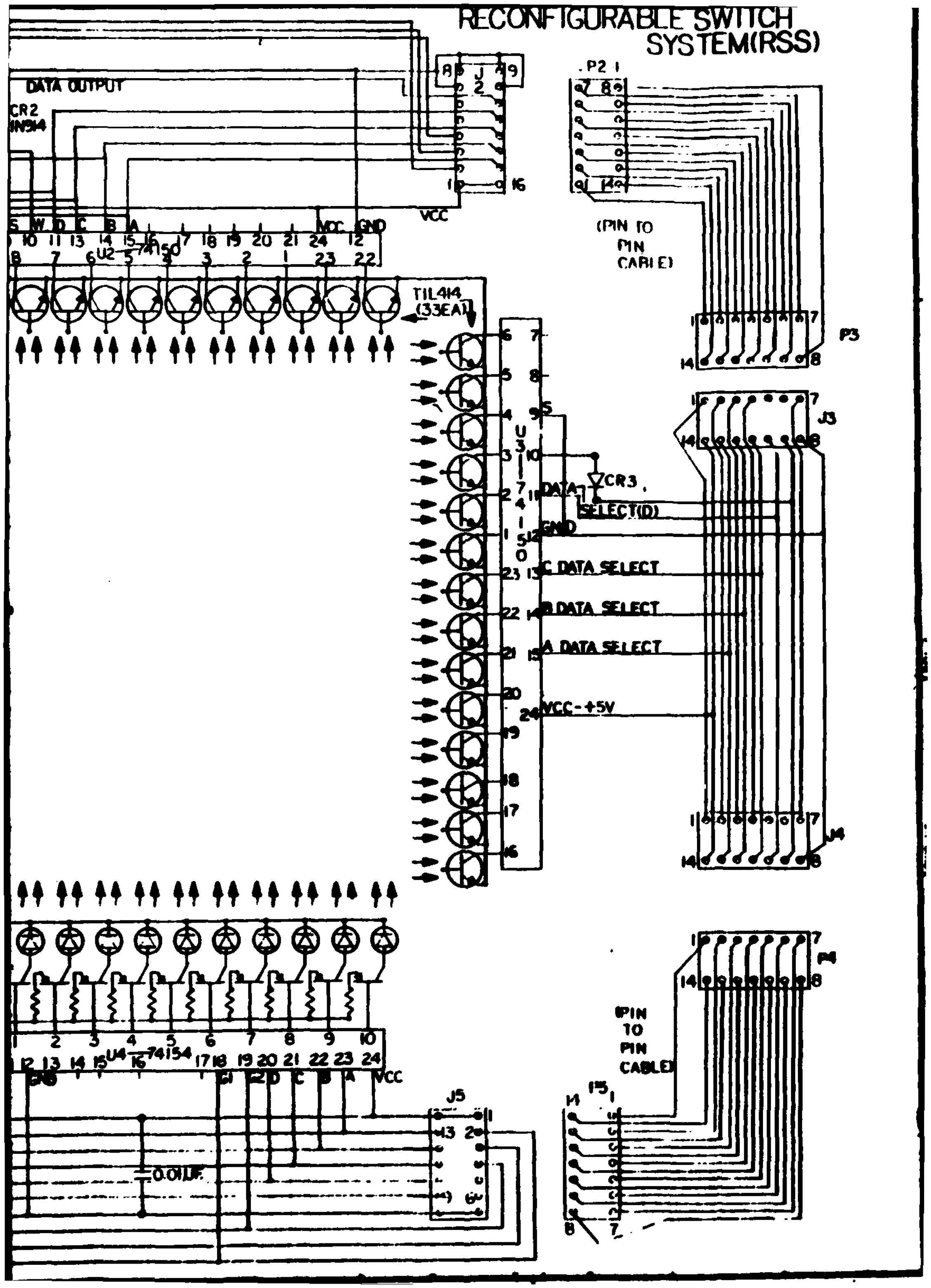


K-12c

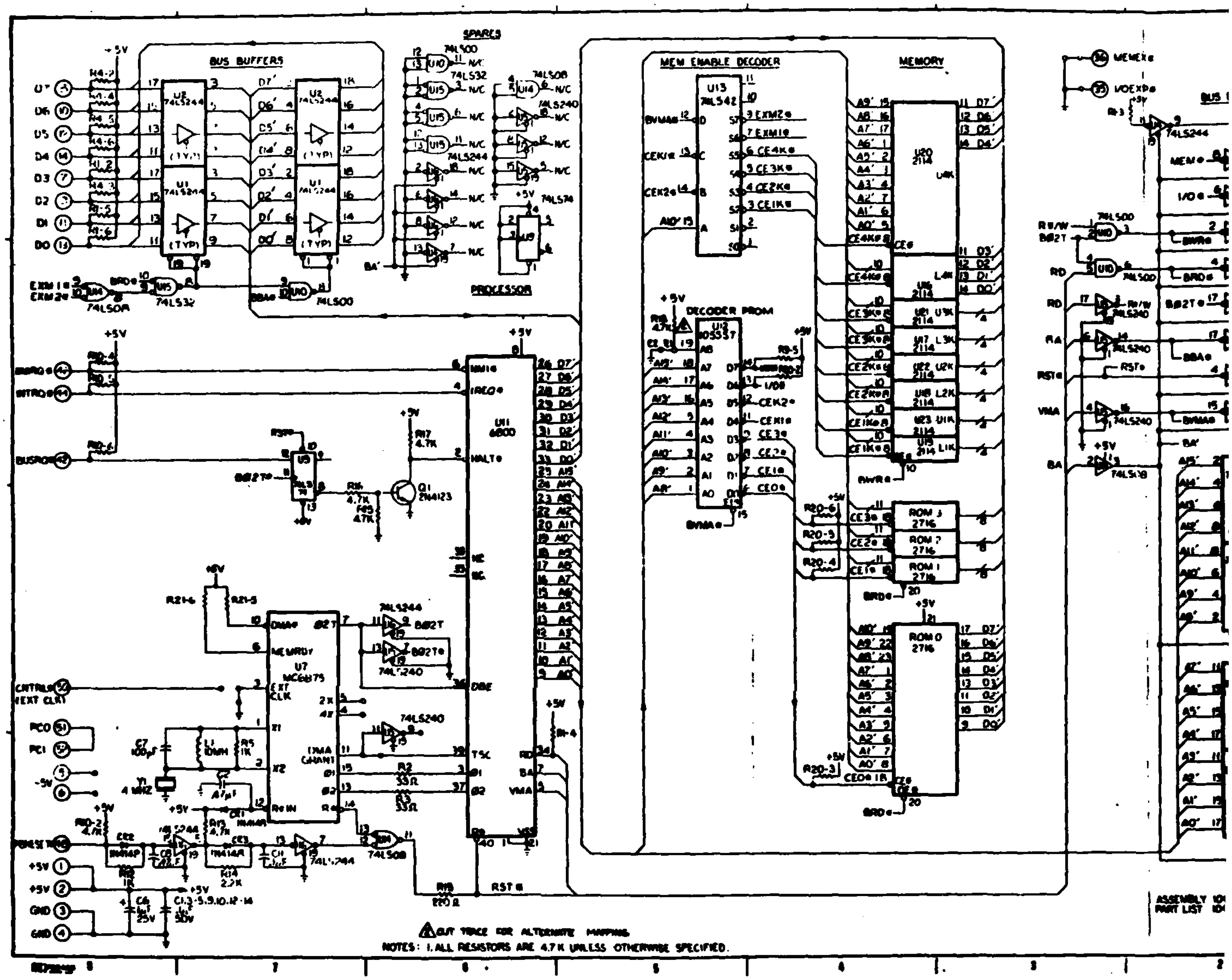
2


GND
GND
N/C
N/C
G2
G1
G1
+5 VCC
J 1
DATA
D
C
B
A
GROUND
CR1 1N914
DATA OUTPUT
CR2 1N914
VCC
U1 74150
U2
2N6727 (33EA)
TIL 39 (33EA)
0.01
10Ω-1/8W (33EA)
U5 74154
U4
0.01UF
GROUND

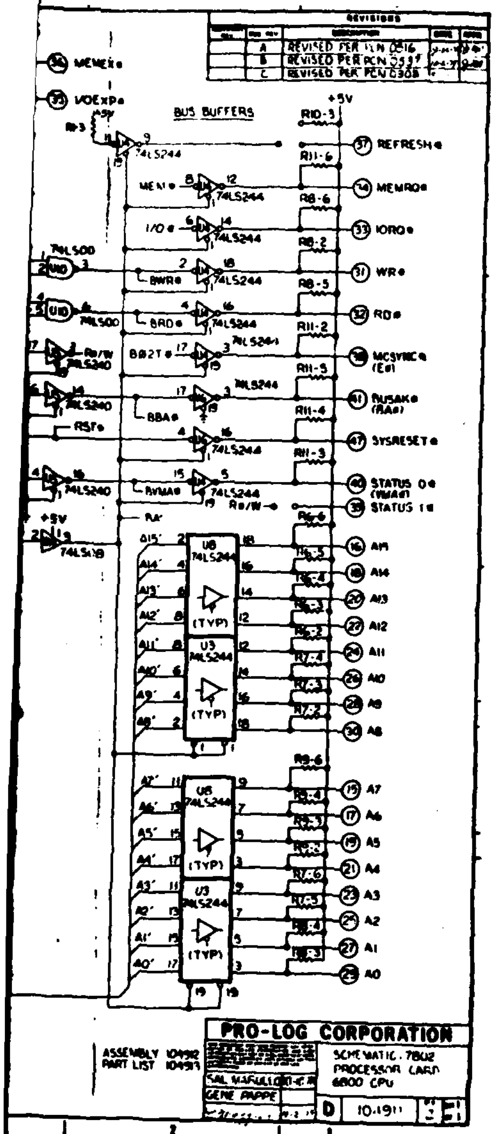
R82-127

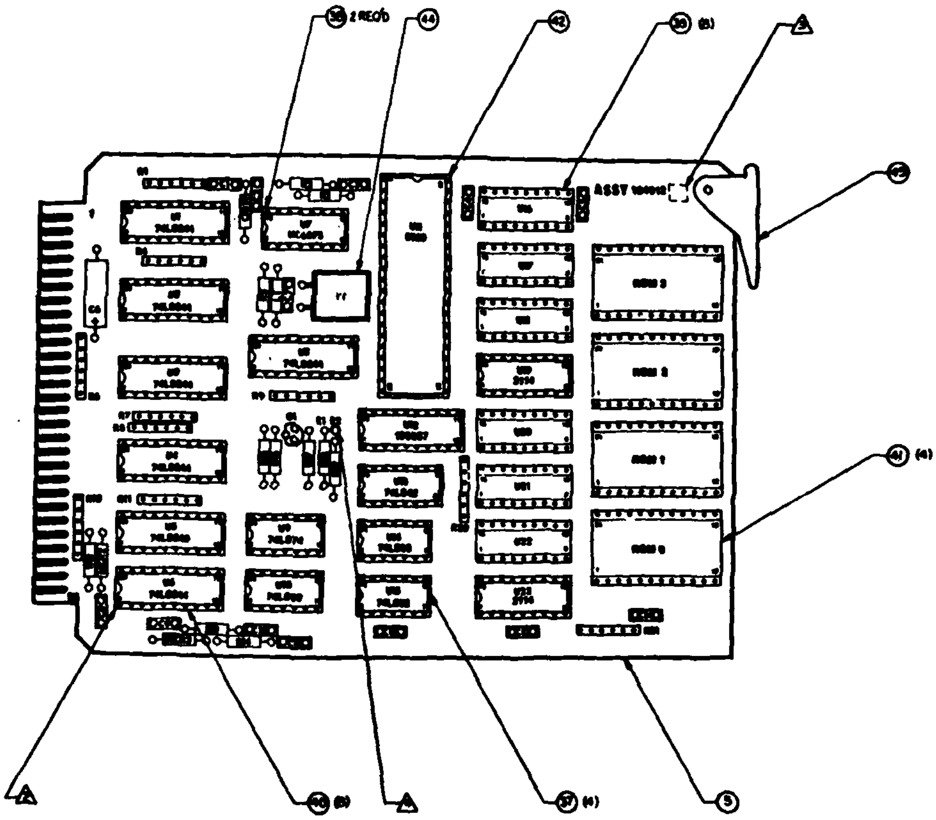


RECONFIGURABLE SWITCH SYSTEM(RSS)
DATA OUTPUT
CR2 1N914
U2 74150
TIL414 (33EA)
P2
J2
(PIN TO PIN CABLE)
P3
J3
J4
P4
U3 74150
CR3
DATA SELECT(D)
GND
C DATA SELECT
B DATA SELECT
A DATA SELECT
VCC-+5V
U4 74154
VCC
0.01UF
J5
P5


BUS BUFFERS
SPARES
PROCESSOR
MEM ENABLE DECODER
MEMORY
DECODER PROM
CUT TRACE FOR ALTERNATE MAPPING
NOTES: 1. ALL RESISTORS ARE 4.7K UNLESS OTHERWISE SPECIFIED.

R82-127





CUT TRACE FOR ALTERNATE MAPPING

IDENTIFY WITH ASSY REV LETTER USING RUBBER STAMP

INDICATES PIN NO. 1 OF SOCKETS (TYP).

1. FOR ASSY PROCEDURES SEE AS1004.

NOTES: UNLESS OTHERWISE SPECIFIED.

SCHEMATIC 104911
PART LIST 104913

ITEM	DESCRIPTION	REF. DESIGNATION
36	2.2K 1/4W,CF,5%	R14
35	1K 1/4W,CF,5%	R5,12
34	33Ω 1/4W,CF,5%	R2,3
33	4.7K 1/4W,CF,5%	R13,15-18
32	220Ω 1/4W,CF,5%	R19
31	4.7K, NETWORK	R1,4,6-11,20,21
14	10μH 10%	L1
13	2N4123	Q1
12	1N4148	CR1-3
11	4MHZ	Y1
10	1.0μf, 50V	C6
9	.47μf, 50V	C2,8
8	.1μf, 50V	C1,3-5,9-14
7	100pf, 50V	C7

PRO-LOG CORPORATION

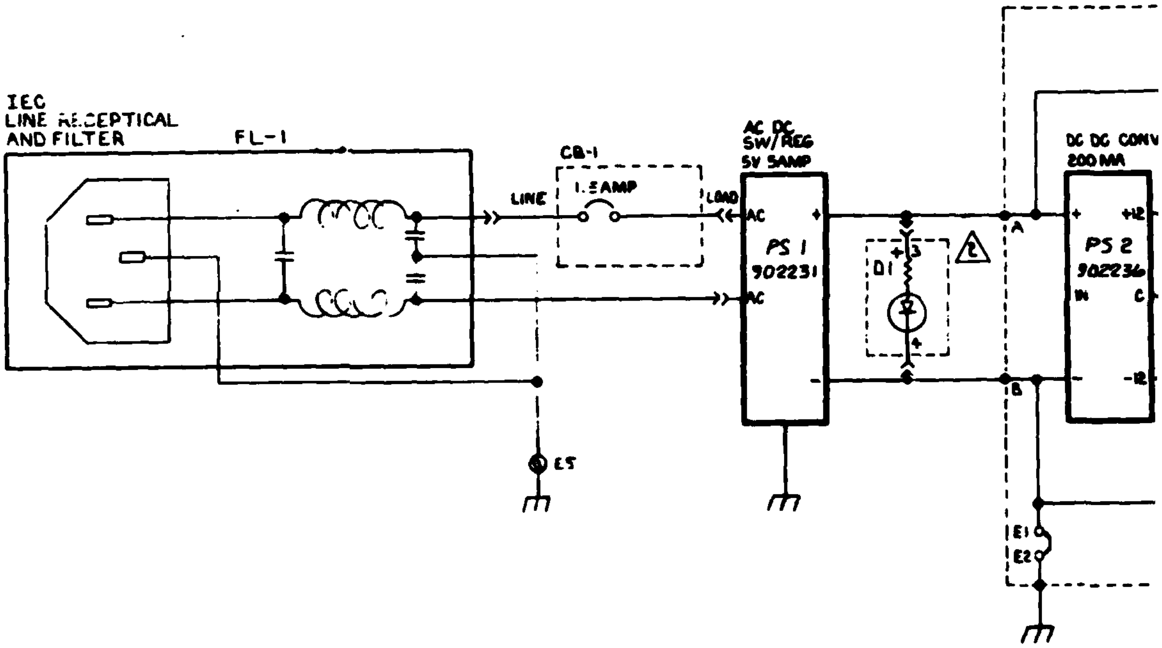
ASSEMBLY, 7802
PROCESSOR CARD
6800 CPU

GENE PAPPE

D | 104912 | 3

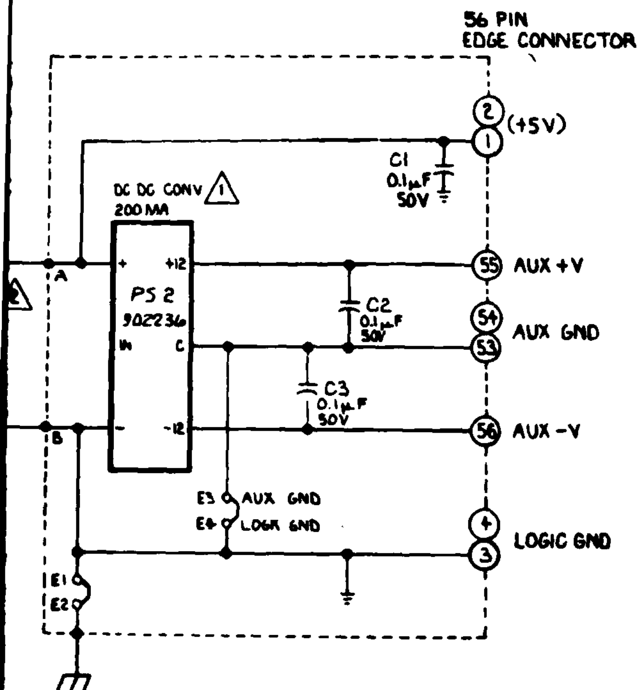
L-1/2

2


IEC
LINE RECEPTICAL
AND FILTER
FL-1
CB-1
1.5AMP
LINE
LOAD
AC DC
SW/REG
5V 5AMP
AC
PS 1
902231
D1
A
B
E5
DC DC CONV
200 MA
PS 2
902236
E1
E2

R82-127

REVISIONS				
REV	DOC REV	DESCRIPTION	DATE	APPR
	A	INITIAL RELEASE PER PCN # 0534	12-5-79	
	B	REVISED PER PCN # 1032		

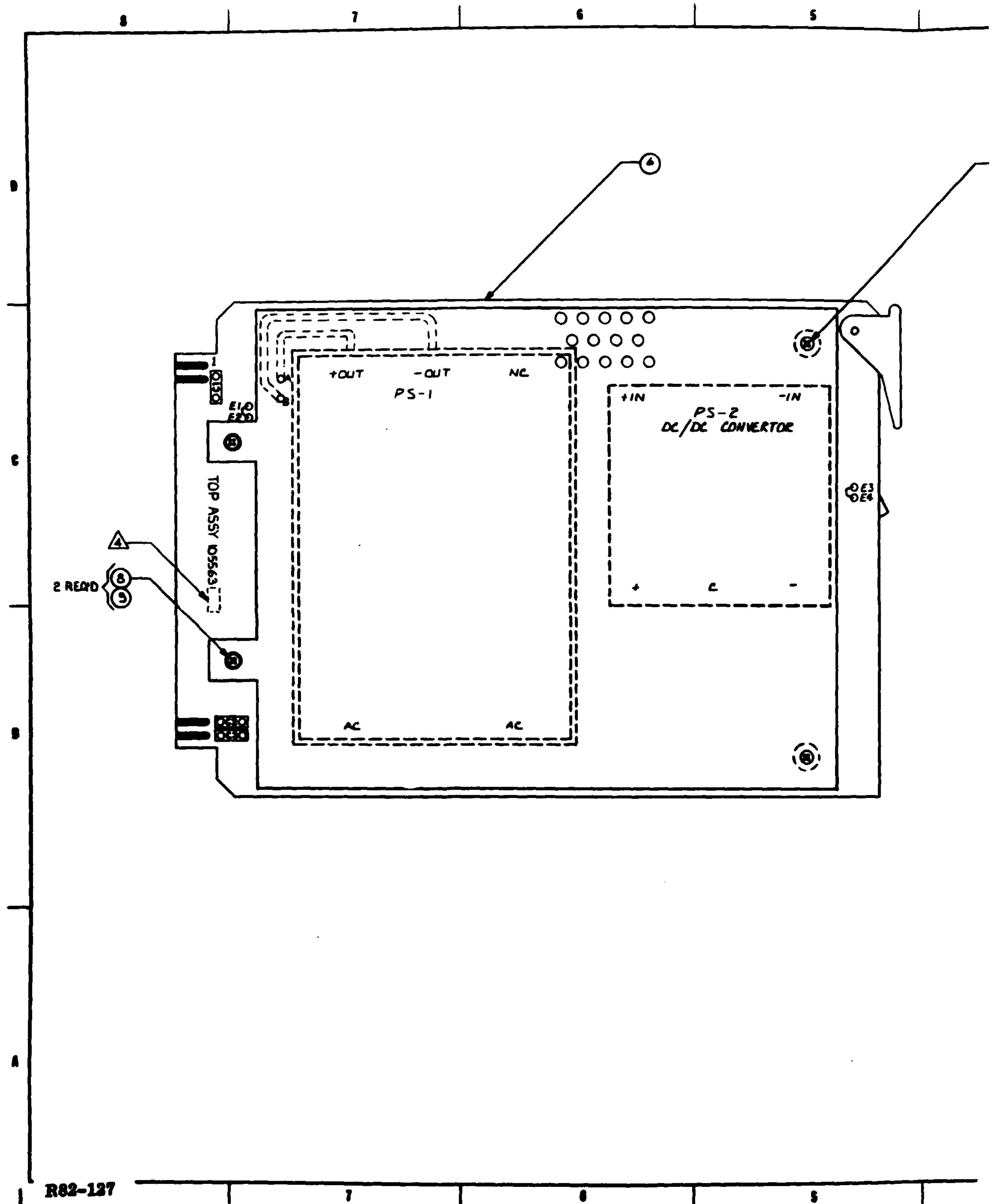


2 D1 = LED INDICATOR (PART OF CE-1)
1 ITEM DELETED ON 7920
NOTES: UNLESS OTHERWISE SPECIFIED

105588	105589	[redacted]		PRO-LOG CORPORATION
105586	105587	C.A.CLARK	7-25-79	SCHEMATIC, 7920/21 IN-RACK POWER SUPPLY
105563	105564		12-5-79	D 105562 B
ASSEMBLY	PARTS LIST			

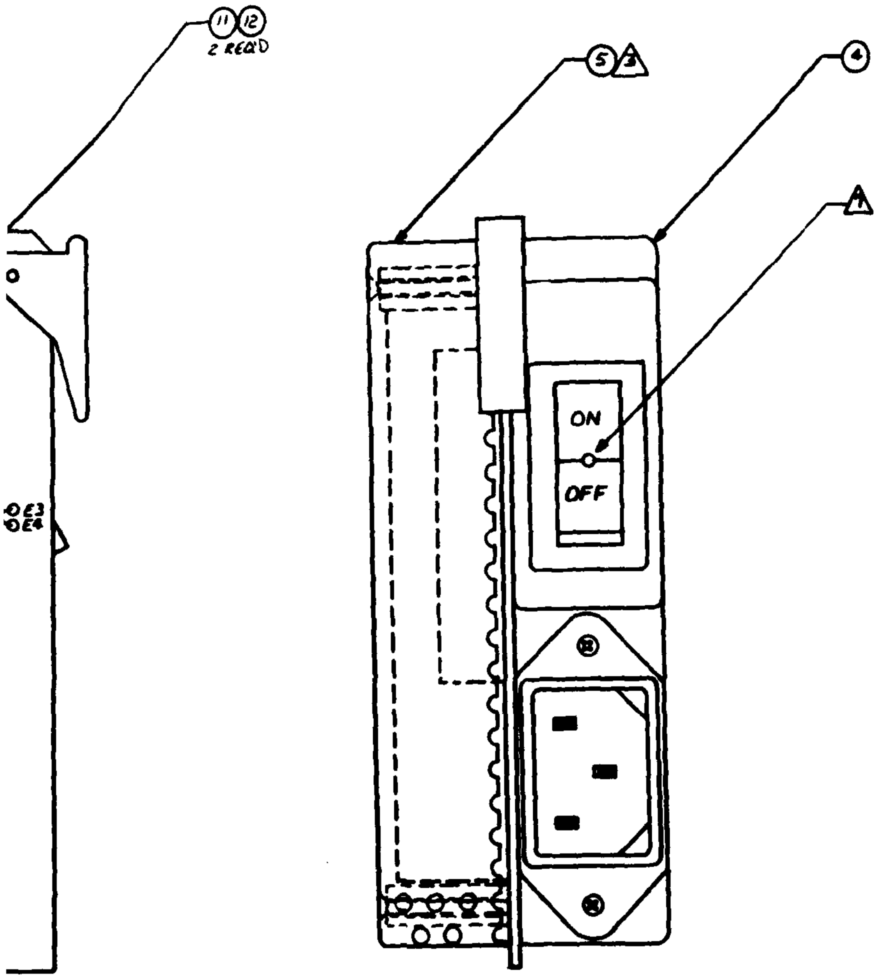
2

L-3



+OUT
-OUT
NC
PS-1
AC
AC
+IN
-IN
PS-2
DC/DC CONVERTOR
+
C
-
E1
E2
E3
E4
TOP ASSY 105563
2 REQ'D

	REVISIONS			
	REV	DESCRIPTION	DATE	APPR
	A	INITIAL RELEASE PER PCN# 0564		
	B	REVISED PER PCN#1092		



NOTES: UNLESS OTHERWISE SPECIFIED
1- ALL WIRES ARE TO BE SOLDERED ON CIRCUIT SIDE OF PWB
2- E1-E4 ARE FOR REF. ONLY AND DO NOT APPEAR ON PWB
3. PERFORATED COVER, ALL LINES SHOWN AS HIDDEN LINES FOR CLARITY
4. IDENTIFY WITH ASSY REV LETTER USING RUBBER STAMP.
5. BOARD TO CONFORM WITH ASSEMBLY PROCEDURES AS 1004.
6. REFERENCE DESIGNATIONS ARE FOR LOCATING PURPOSES ONLY AND MAY NOT APPEAR ON ACTUAL PART.
7. WHEN POWER SWITCH IS PLACED TO THE ON POSITION THE RED LED, CENTER OF SWITCH WILL ILLUMINATE.

SCHEMATIC NO. 105562
PARTS LIST NO. 105564

ITEM	DESCRIPTION	REF. DESIGNATION

PRO-LOG CORPORATION

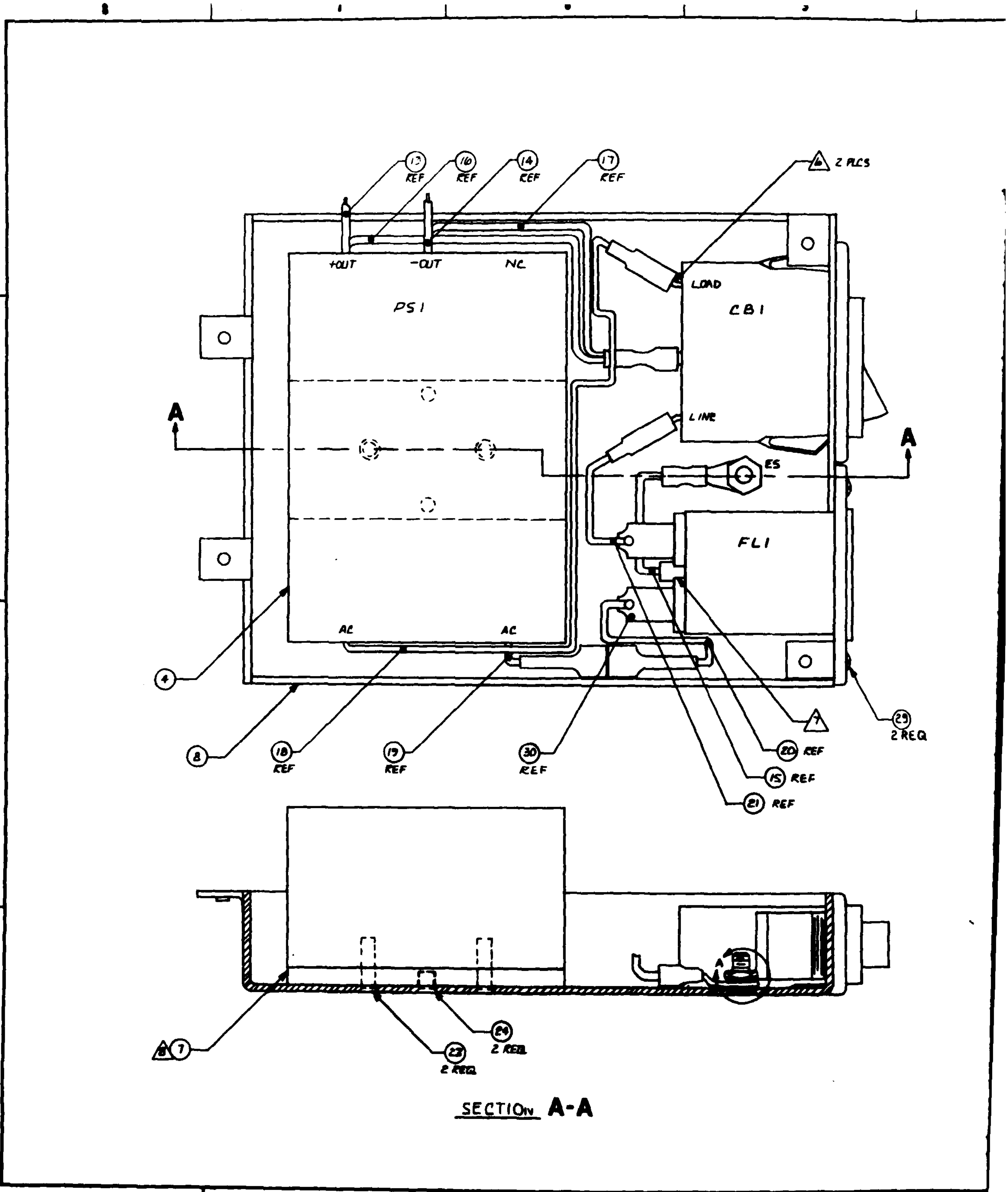
[redacted] ASSEMBLY, 7721 IN RACK POWER SUPPLY

APPROVED 10-29-76

D 105563 B SHT 1 OF 1

L-4

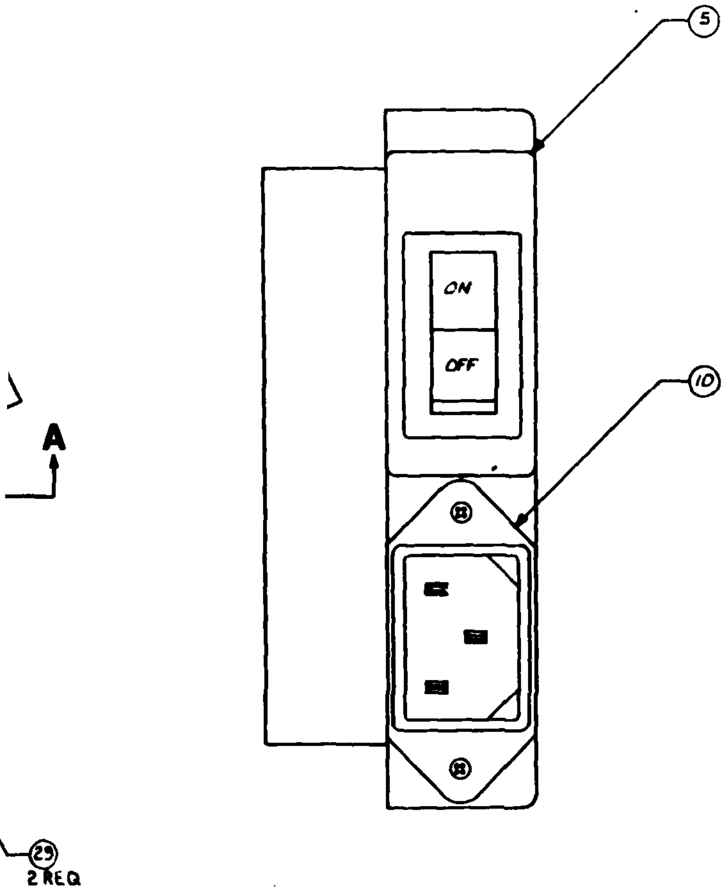
2



SECTION A-A

R82-127

REVISIONS				
	DOC REV	DESCRIPTION	DATE	APPR
	A	INITIAL RELEASE PER PCN # 0564	12-5-79	
	B	REVISED PER PCN 0855		



NOTES: UNLESS OTHERWISE SPECIFIED
1. SCALE: 2/1
2. SOME ITEMS OR LINES ARE OMITTED FOR CLARITY
3. IDENTIFY ASSY USING TAG WITH PART NO. & REVISION
4. COVER CUTAWAY IN SIDE VIEW FOR CLARITY
5. SEE WIRE TABLE FOR POINT TO POINT HOOK-UPS
6. BEND 30° LINE & LOAD TERMINALS, PRIOR TO INSTALLATION OF C.B.
7. BEND UP 45° (GND TERMINAL)
8. APPLY THERMAL GREASE TOP & BOTTOM
9. REF DESIGNATIONS ARE FOR REF ONLY AND MAY NOT APPEAR ON ACTUAL PART
10. SEE SHEET 2 FOR WIRE HOOK-UP OF PS1 & FL1

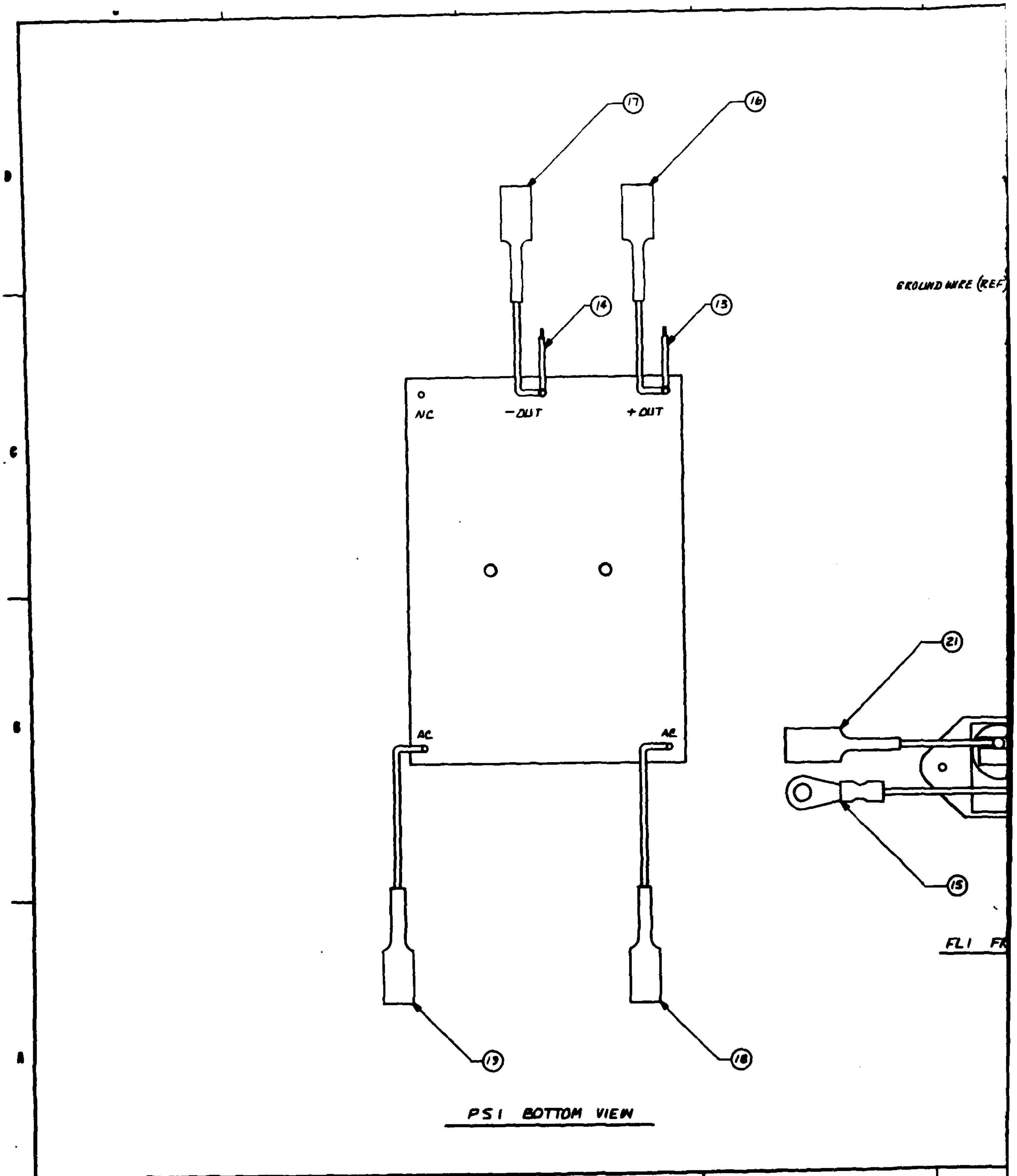
WIRE TABLE 5					
FROM:	WIRE ITEM NO.	WIRE COLOR	TO:	WIRE ITEM NO.	WIRE COLOR
FL1 (GRN)	15	GRN	ES, PEM STUD	—	—
FL1 (WHT)	20	WHT	PS1 (AC)	19	WHT
FL1 (BLK)	21	BLK	CB1 (LINE TERM)	—	—
PS1 (+OUT)	13	RED	N/C	—	—
PS1 (-OUT)	14	BLK	N/C	—	—
PS1 (+OUT)	16	RED	CB1 (PIN 3)	—	—
PS1 (-OUT)	17	BLK	CB1 (PIN 4)	—	—
PS1 (AC)	18	BLK	CB1 (LOAD TERM)	—	—
PS1 (AC)	19	WHT	FL1 (WHT)	20	WHT

SCHEMATIC NO. 105562
PARTS LIST NO. 105587

PRO-LOG CORPORATION				
	10-23-79	ASSEMBLY, (COVER) 7921 IN-RACK POWER SUPPLY		
	12-5-79	D	105586	SHT 1 OF 2

L-5a

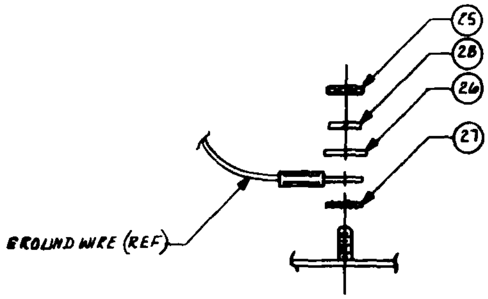
2



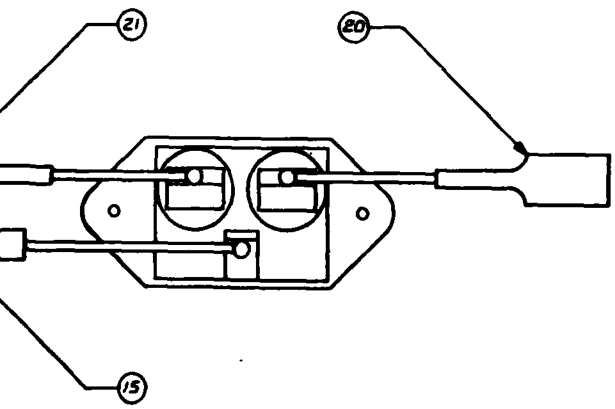
PS1 BOTTOM VIEW

R82-127

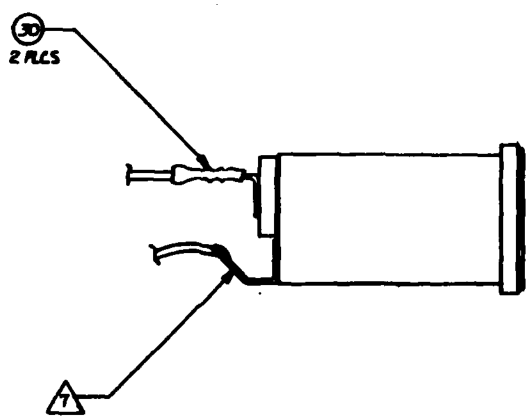
REVISIONS				
ASSY/DASH REV	DOC REV	DESCRIPTION	DATE	APPR



DETAIL "A"



FL1 FRONT VIEW

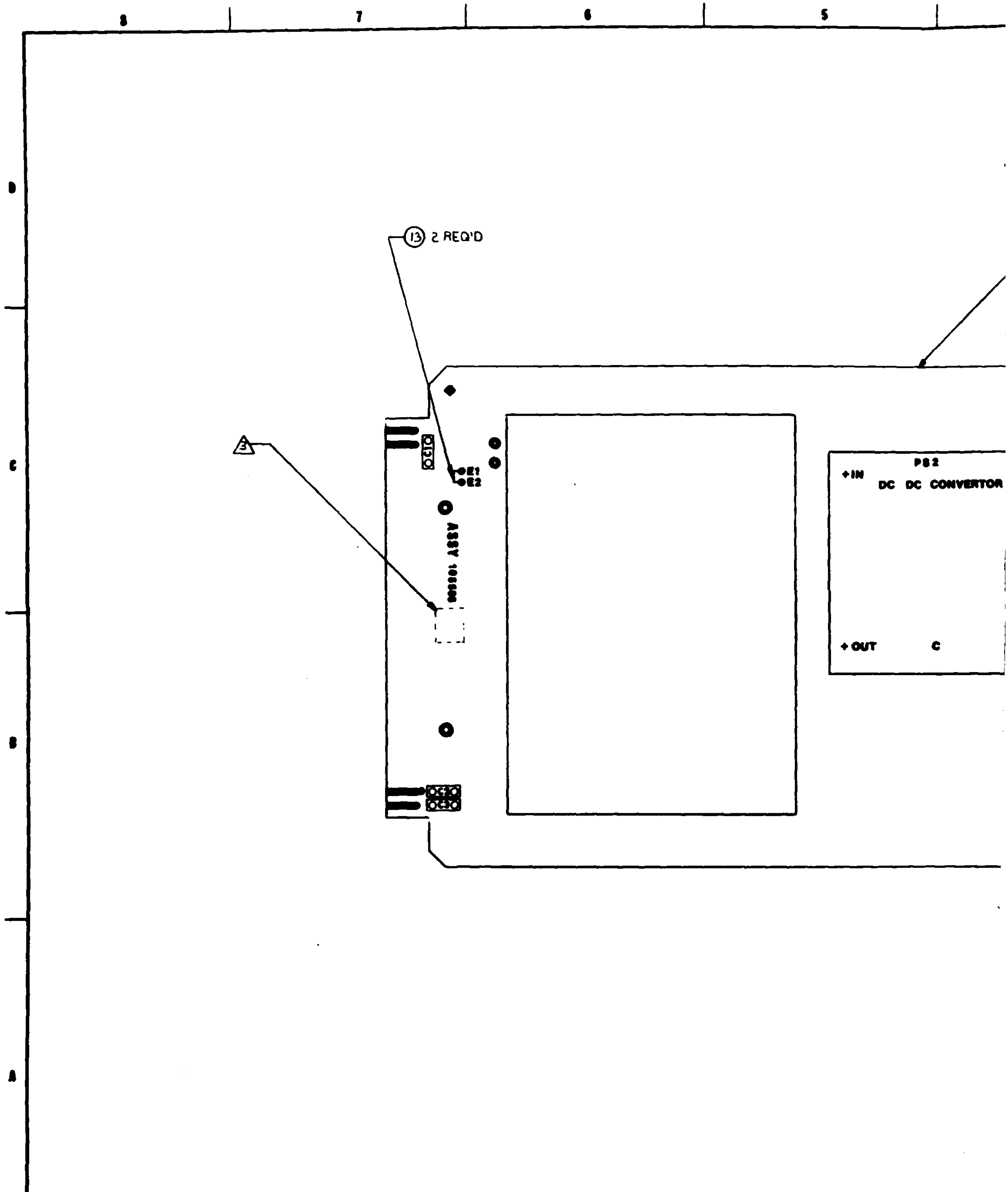


FL1 SIDE VIEW

PRO-LOG CORPORATION		
[redacted]		ASSEMBLY, (COVER) 7921 IN-RACK POWER SUPPLY
MARULLO	11-9-79	
J. Maggio	12-5-79	D 105586 REV B SH 2 OF 2

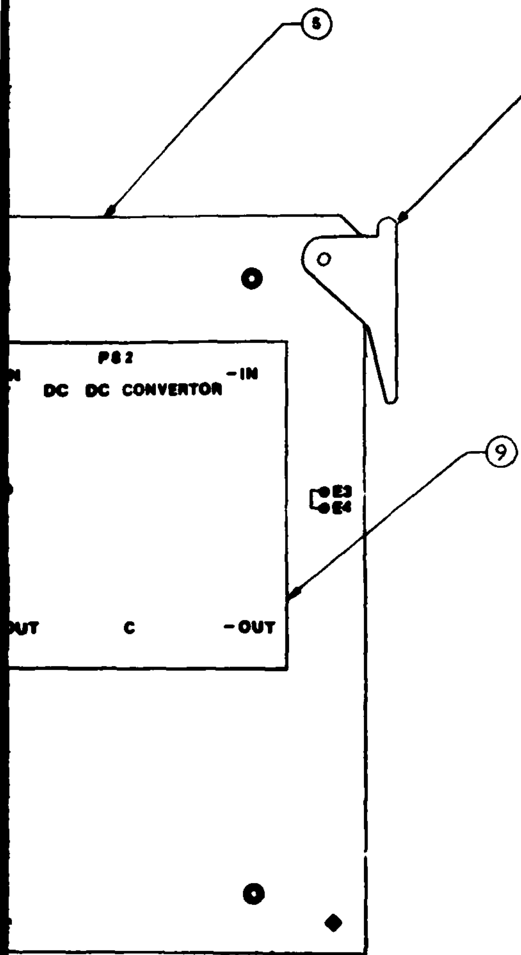
L-5b

2



R82-127

REVISIONS				
	A	INITIAL RELEASE PER PCN # 0564	12-5-7	



NOTES : UNLESS OTHERWISE SPECIFIED
1- FOR ASSEMBLY PROCEDURES SEE AS1004
2- REF DESIGNATION ARE FOR LOCATING PURPOSE ONLY & MAY NOT APPEAR ON ACTUAL PART
3 - IDENTIFY WITH ASSEMBLY REV LETTER USING RUBBER STAMP

SCHEMATIC NO. 105562
PARTS LIST NO. 105587

ITEM	DESCRIPTION	REF. DESIGNATION
7	.01 µF, 50V, CER	C1, C2, C3
6		
5	105561	PWB

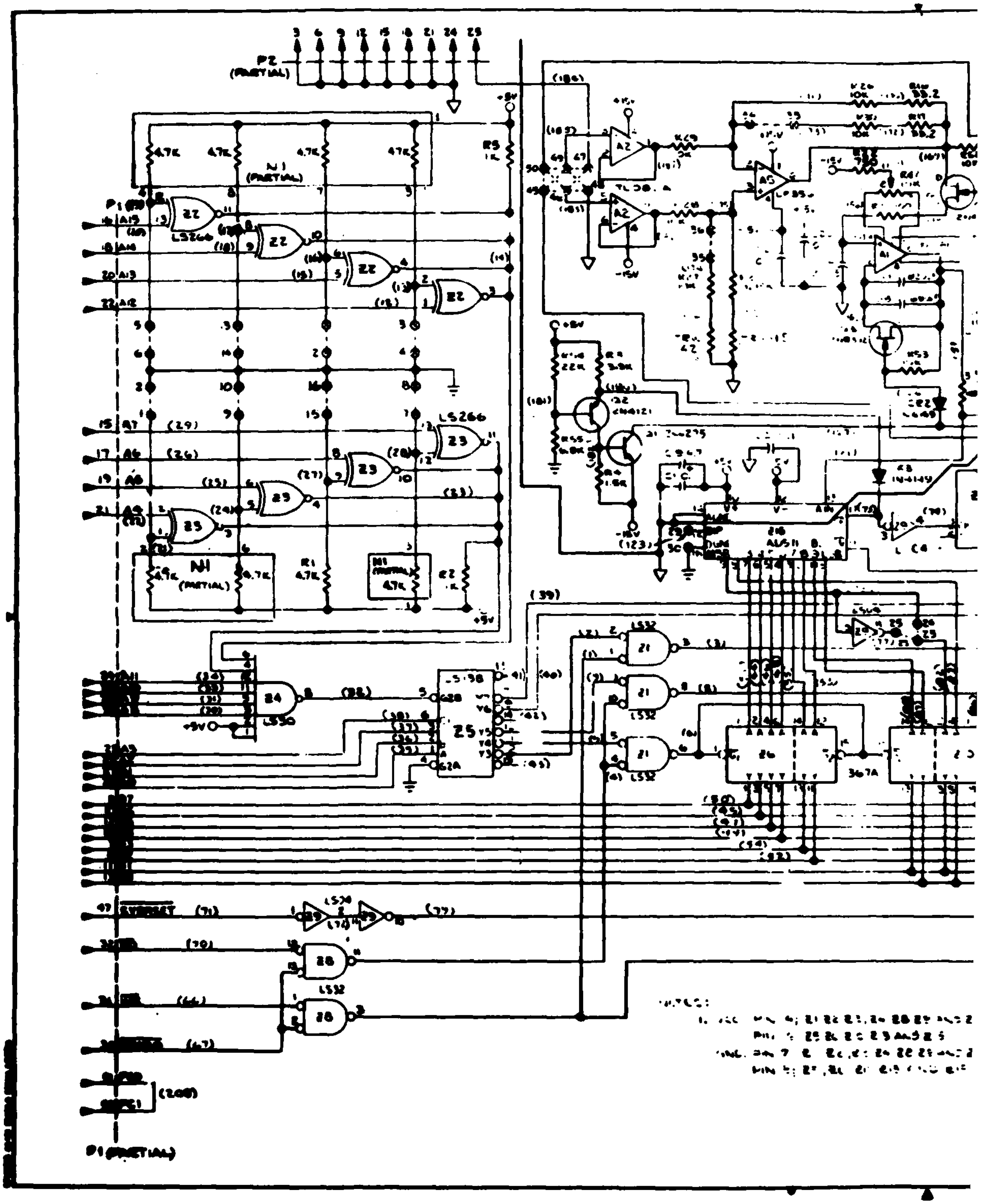
PRO-LOG CORPORATION

ASSY PWB 7921
IN RACK POWER
SUPPLY

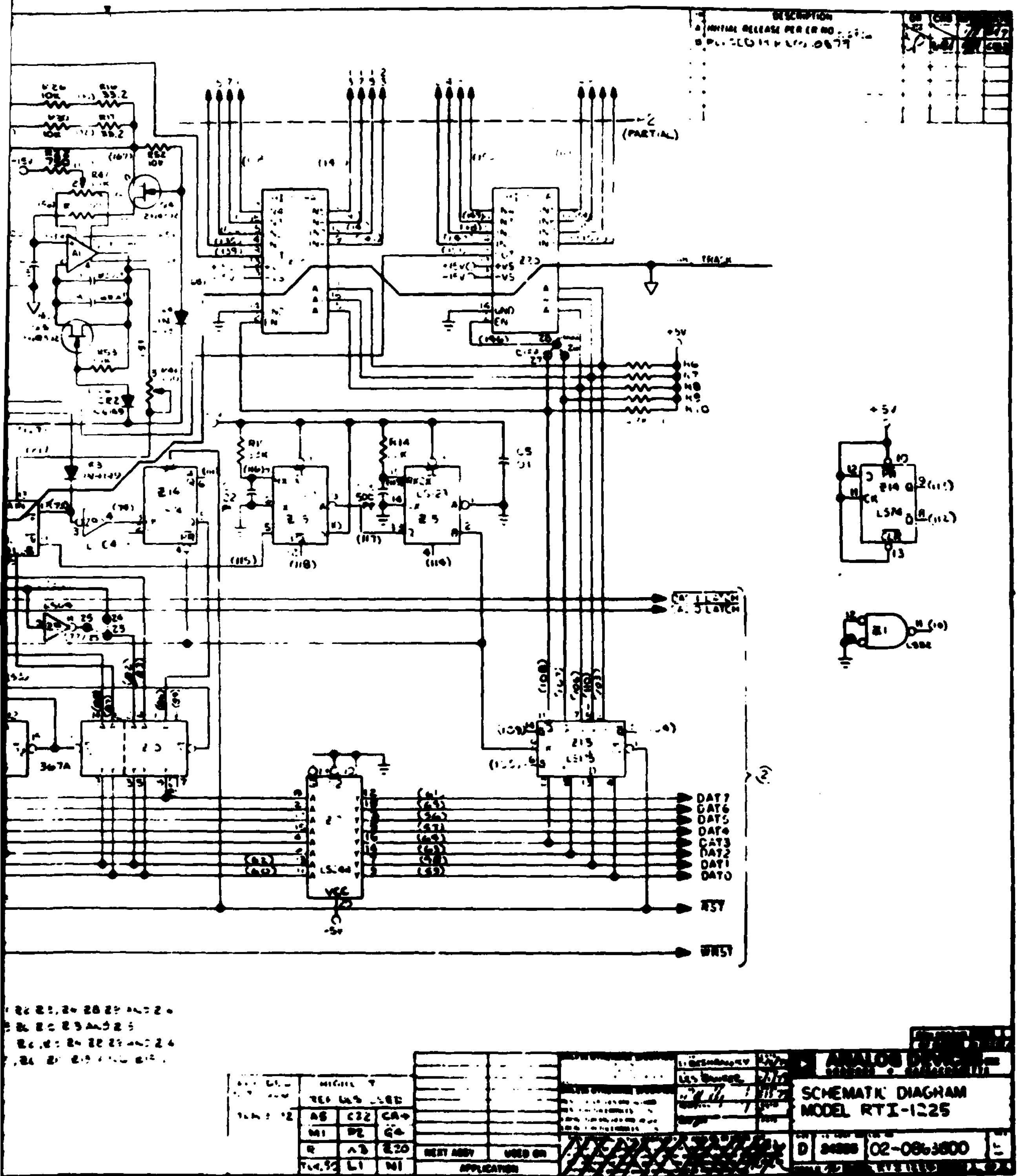
[illegible]
MARULLO 10-23-79
12-5-7

D 105588

L-6


P2 (PARTIAL)
P1 (PARTIAL)
LS266
LS30
LS138
LS32
ALS11
N1 (PARTIAL)
TL084
LF356
4.7K
+5V
-15V
+15V
2N4121
1N4149

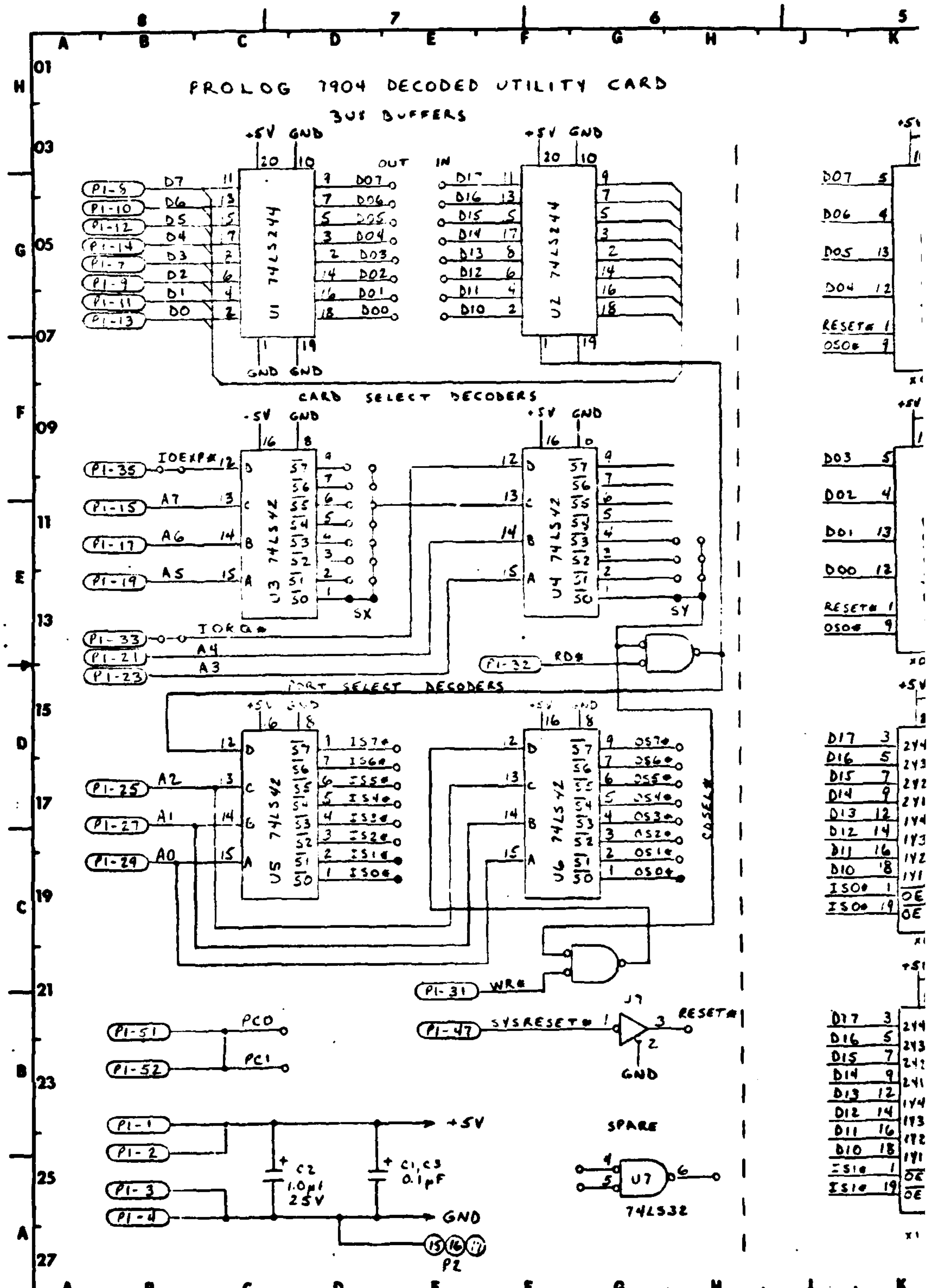
R82-127



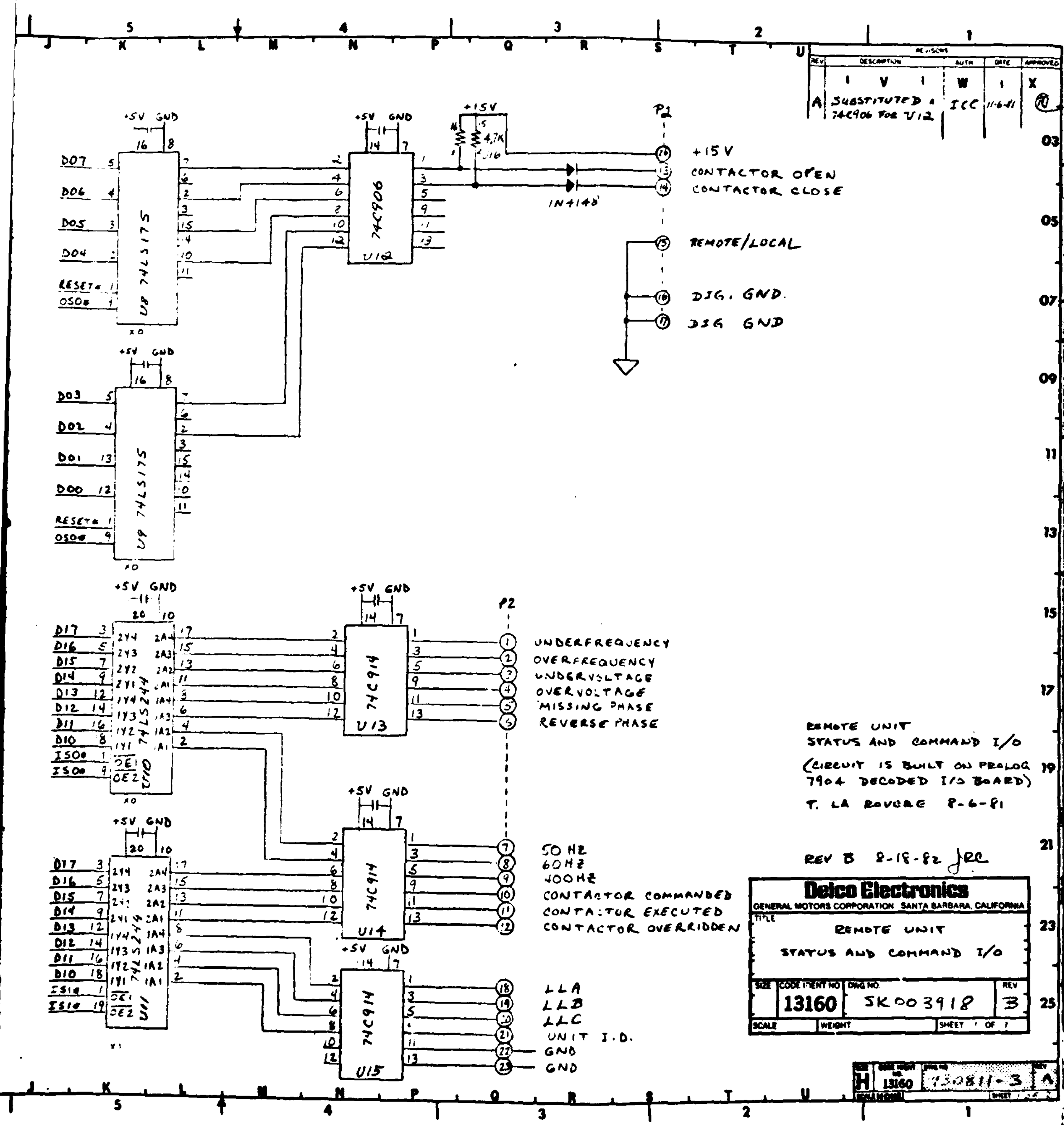
DESCRIPTION
INITIAL RELEASE PER ER NO.
(PARTIAL)
TRACK
+5V
+5V
Z14
LS74
Z1
LS00
LS123
LS04
A1
LATCH
DAT7
DAT6
DAT5
DAT4
DAT3
DAT2
DAT1
DAT0
RST
WRST
VCC
REF DES USED
A5
C22
CR4
M1
P2
Q4
A3
Z20
L1
N1
NEXT ASSY
USED ON
APPLICATION
ANALOG DEVICES
SCHEMATIC DIAGRAM
MODEL RTI-1225
D
02-086.3800

2

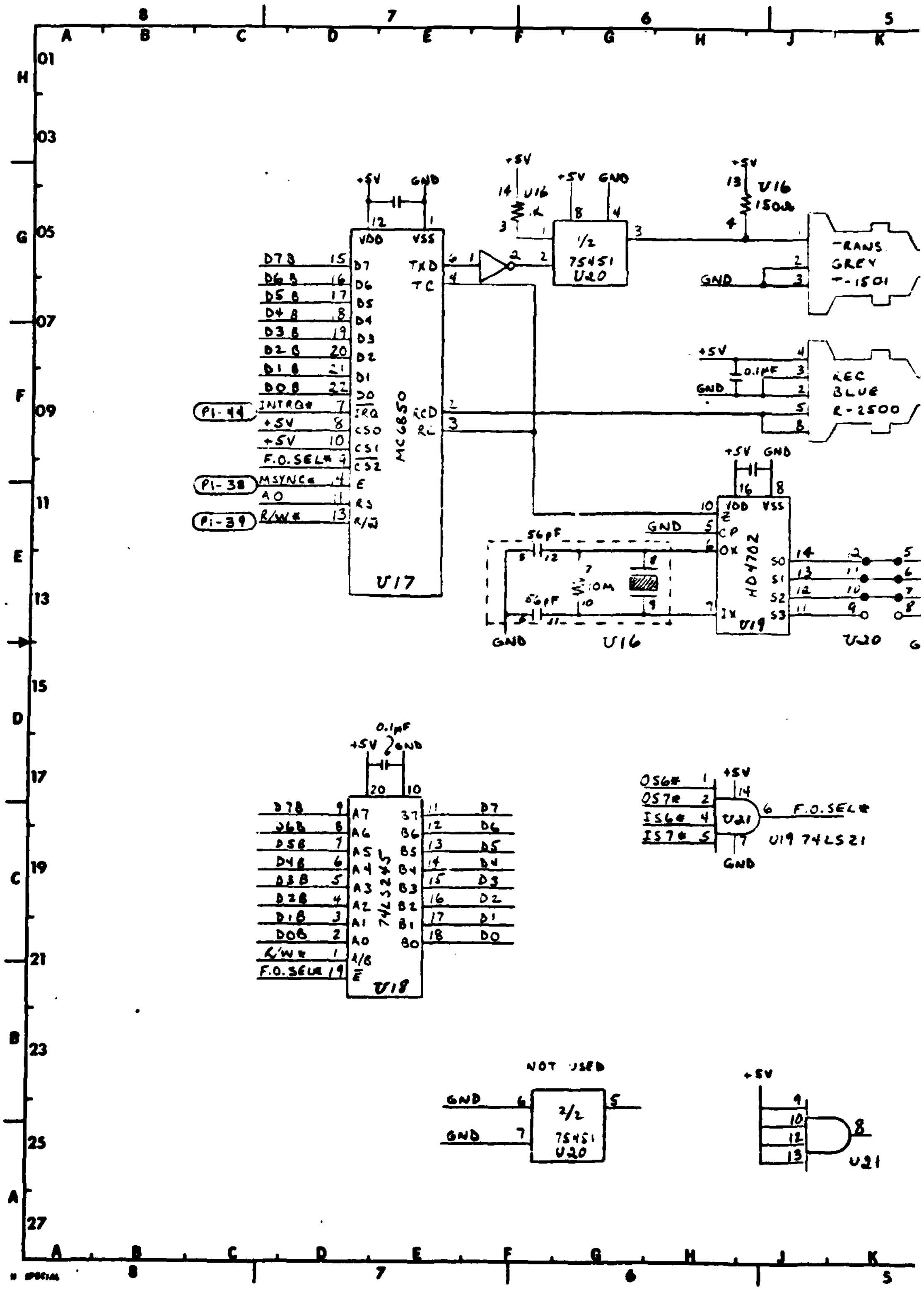
I-7



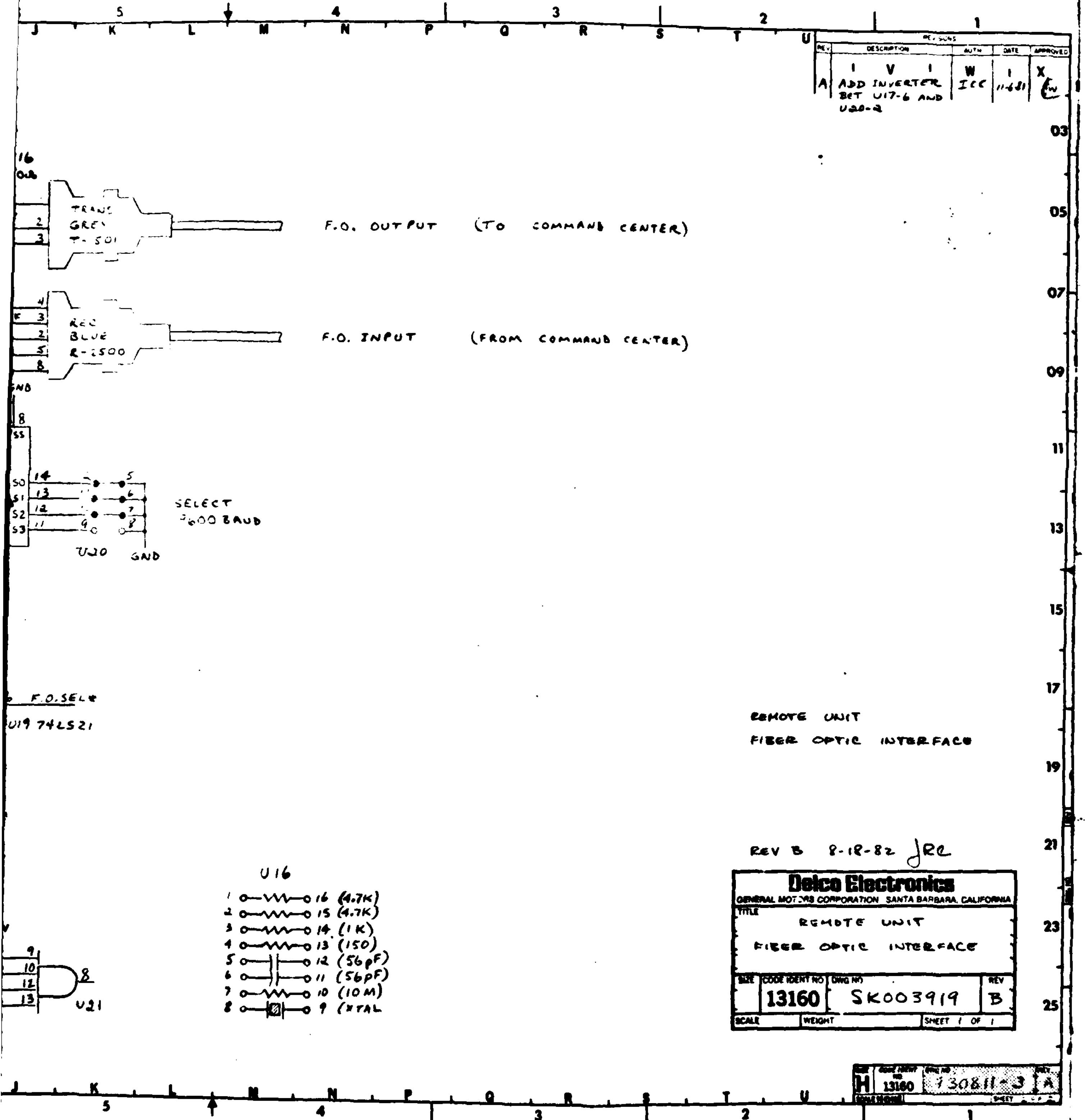
FROLOG 7904 DECODED UTILITY CARD
BUS BUFFERS
CARD SELECT DECODERS
PORT SELECT DECODERS
74LS244
74LS42
74LS32
SPARE
+5V
GND
RESET*
SYSRESET*
IORQ*
IOEXP*
RD*
WR*
CASEL*
C2 1.0µf 25V
C1, C3 0.1µF
P2


REMOTE UNIT STATUS AND COMMAND I/O
(CIRCUIT IS BUILT ON PROLOG 7904 DECODED I/O BOARD)
T. LA ROVERE 8-6-81
REV B 8-18-82
SUBSTITUTED 74C906 FOR U12
ICC 11-6-81
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA
TITLE
REMOTE UNIT
STATUS AND COMMAND I/O
13160
SK003918
B
13160
130811-3
+15 V
CONTACTOR OPEN
CONTACTOR CLOSE
1N4148
REMOTE/LOCAL
DIG. GND.
DIG GND
UNDERFREQUENCY
OVERFREQUENCY
UNDERVOLTAGE
OVERVOLTAGE
MISSING PHASE
REVERSE PHASE
50 HZ
60 HZ
400 HZ
CONTACTOR COMMANDED
CONTACTOR EXECUTED
CONTACTOR OVERRIDDEN
LLA
LLB
LLC
UNIT I.D.
GND
GND
U8 74LS175
U9 74LS175
74C906
U12
74C914
U13
U14
U15
74LS244
U10
U11
4.7K
U16
P2
+5V
GND
DO7
DO6
DO5
DO4
DO3
DO2
DO1
DO0
RESET
DI7
DI6
DI5
DI4
DI3
DI2
DI1
DI0
ISO0
ISI0

2

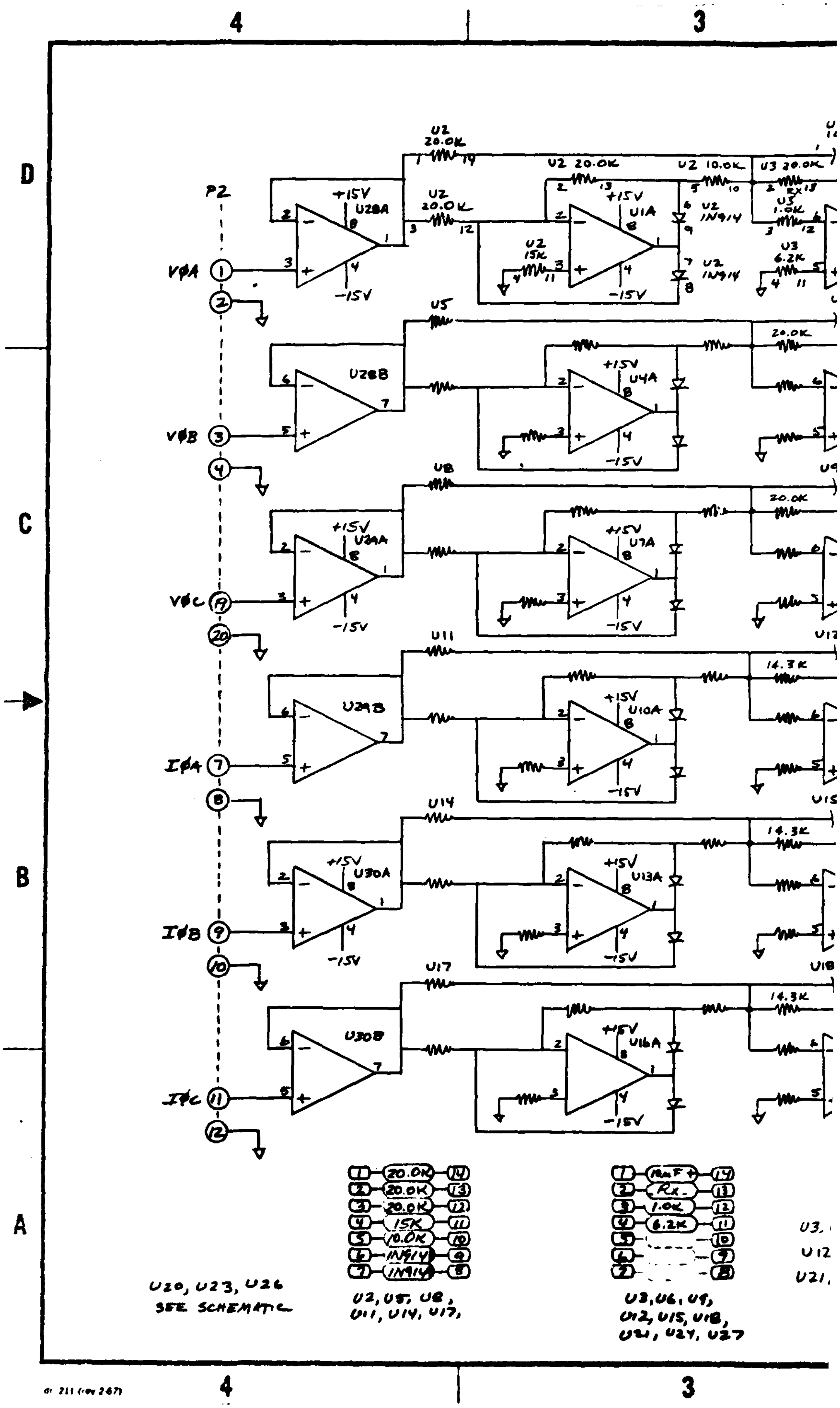


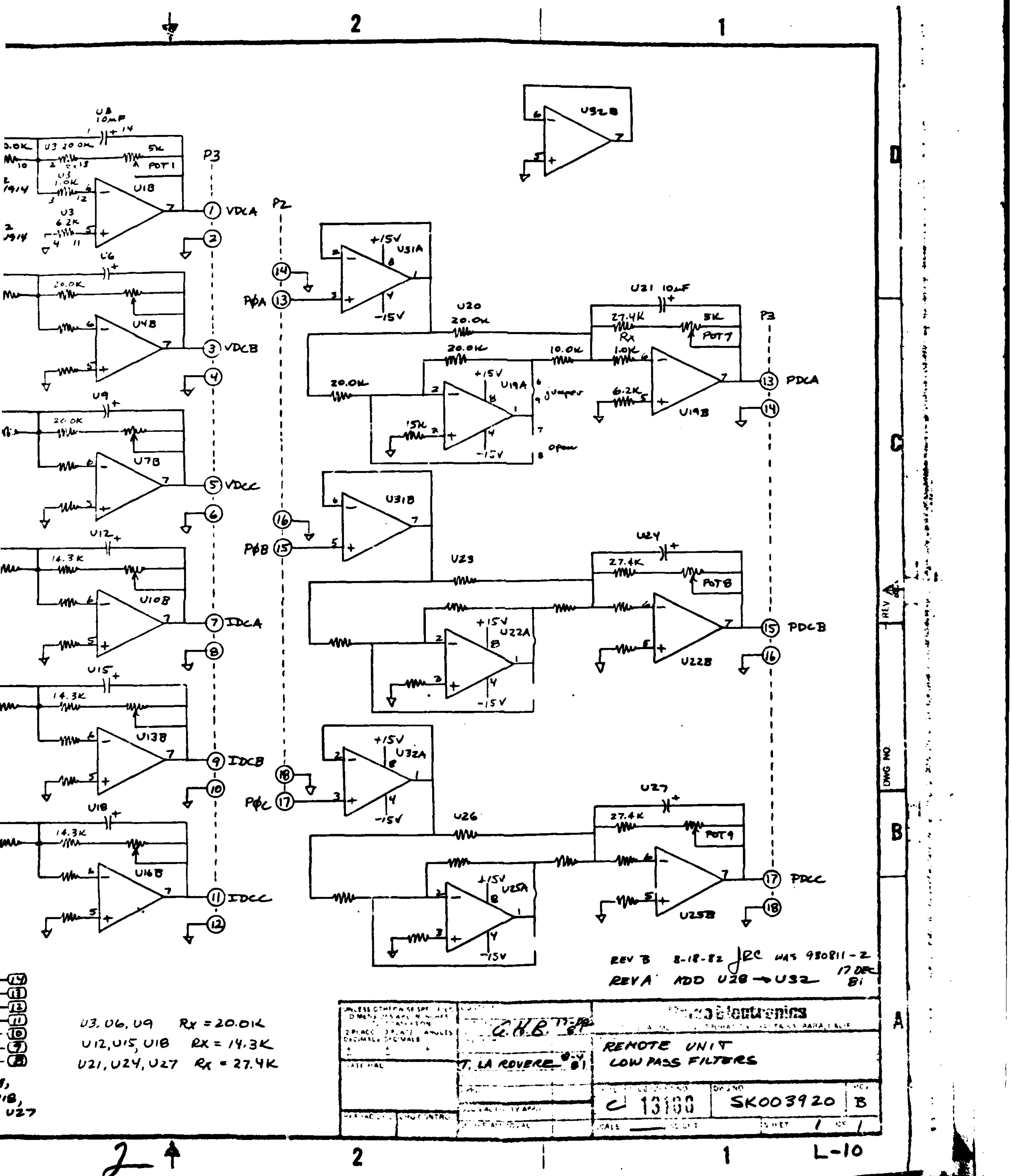
+5V
GND
VDD
VSS
D7B
D6B
D5B
D4B
D3B
D2B
D1B
D0B
INTRQ#
+5V
F.O.SEL#
MSYNC#
A0
R/W#
P1-44
P1-38
P1-39
D7
D6
D5
D4
D3
D2
D1
D0
IRQ
CS0
CS1
CS2
E
RS
R/W
TXD
TC
RCD
RC
MC6850
U17
U16
1/2
75451
U20
TRANS
GREY
T-1501
REC
BLUE
R-2500
0.1µF
HD4702
CP
OX
IX
S0
S1
S2
S3
U19
56pF
10M
0.1µF
A7
A6
A5
A4
A3
A2
A1
A0
T/R
B7
B6
B5
B4
B3
B2
B1
B0
74LS245
U18
OS6#
OS7#
IS6#
IS7#
U21
F.O.SEL#
U19 74LS21
NOT USED
2/2
U21


A ADD INVERTER BET U17-6 AND U20-2
TRANS GREY T-501
F.O. OUTPUT (TO COMMAND CENTER)
REC BLUE R-2500
F.O. INPUT (FROM COMMAND CENTER)
SELECT 9600 BAUD
U20
GND
F.O. SEL
U19 74LS21
REMOTE UNIT
FIBER OPTIC INTERFACE
REV B 8-18-82
U16
1 — 16 (4.7K)
2 — 15 (4.7K)
3 — 14 (1K)
4 — 13 (150)
5 — 12 (56pF)
6 — 11 (56pF)
7 — 10 (10M)
8 — 9 (XTAL
U21
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA
REMOTE UNIT
FIBER OPTIC INTERFACE
13160
SK003919
B
SHEET 1 OF 1
H 13160 130811-3 A

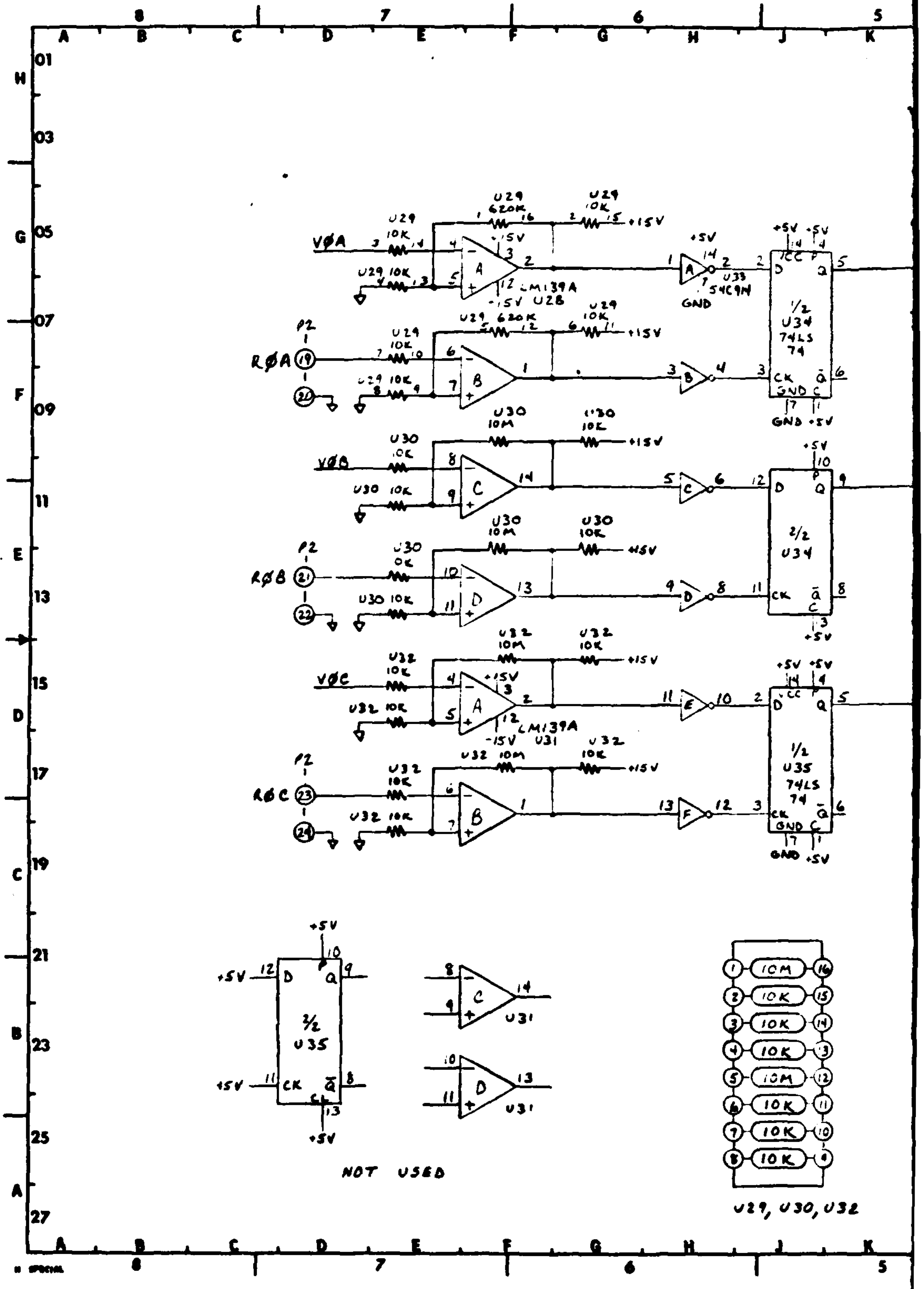
L-9

2

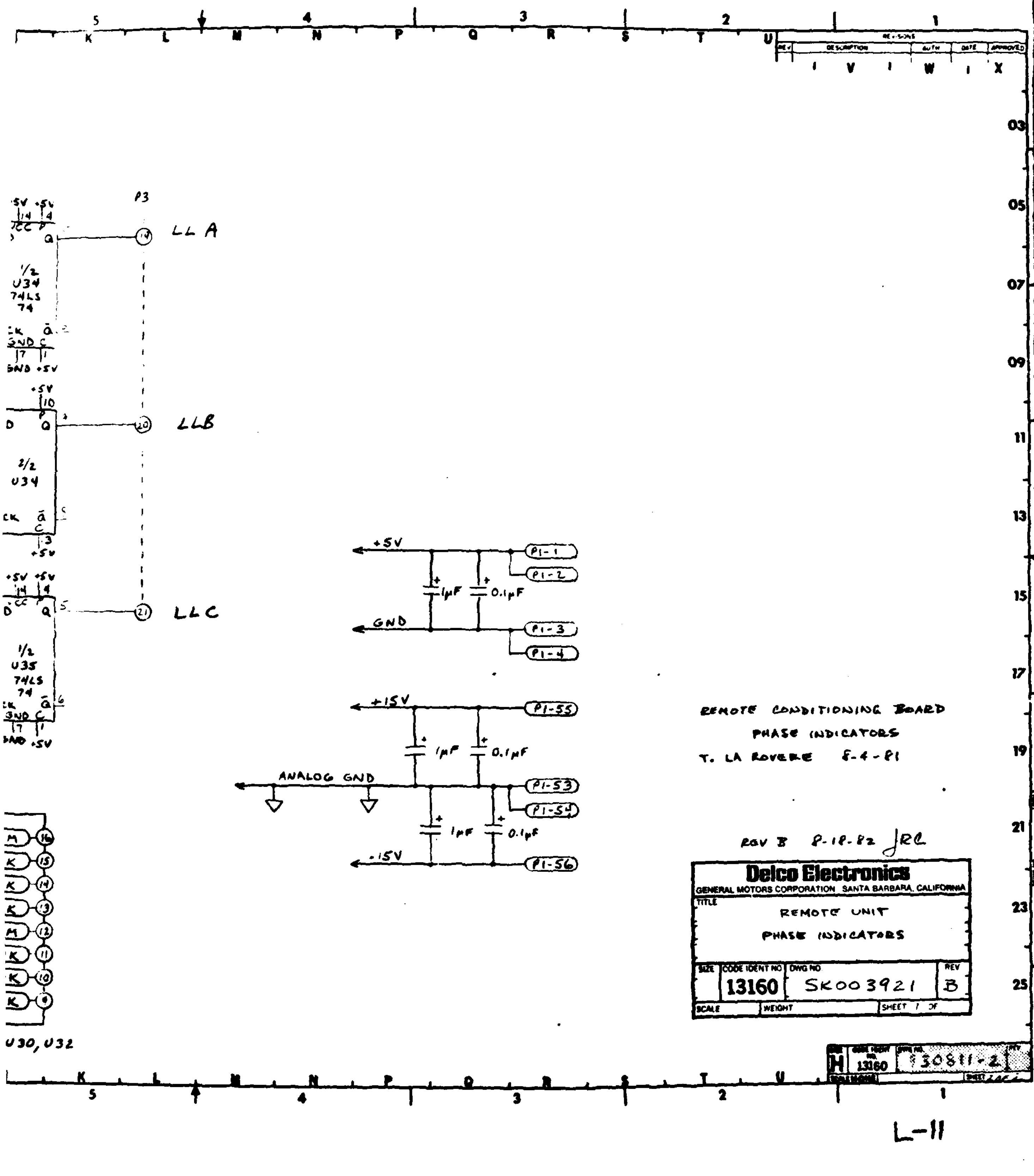

P2
VØA
VØB
VØC
IØA
IØB
IØC
U28A
U28B
U29A
U29B
U30A
U30B
U1A
U4A
U7A
U10A
U13A
U16A
+15V
-15V
U2 20.0K
U2 10.0K
U2 15K
U2 1N914
U3 20.0K
U3 1.0K
U3 6.2K
U5
U8
U11
U14
U17
20.0K
14.3K
20.0K
15K
10.0K
1N914
1.0K
6.2K
Rx
U20, U23, U26
SEE SCHEMATIC
U2, U5, U8,
U11, U14, U17,
U3, U6, U9,
U12, U15, U18,
U21, U24, U27



REV B 8-18-82 JRC WAS 930811-2
REV A ADD U28 → U32 17 DEC 81
U3, U6, U9 Rx = 20.0K
U12, U15, U18 Rx = 14.3K
U21, U24, U27 Rx = 27.4K
REMOTE UNIT
LOW PASS FILTERS
T. LA ROVERE
SK003920
B
L-10



VØA
RØA
VØB
RØB
VØC
RØC
P2
LM139A
U28
U31
54C94
1/2 U34 74LS 74
2/2 U34
1/2 U35 74LS 74
2/2 U35
NOT USED
10M
10K
U29, U30, U32



P3
LL A
1/2
U34
74LS
74
LLB
2/2
U34
LLC
1/2
U35
74LS
74
U30, U32
+5V
GND
P1-1
P1-2
P1-3
P1-4
1µF
0.1µF
+15V
P1-55
ANALOG GND
P1-53
P1-54
-15V
P1-56
REMOTE CONDITIONING BOARD
PHASE INDICATORS
T. LA ROVERE 8-4-81
REV B 8-18-82 JRL
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA
TITLE
REMOTE UNIT
PHASE INDICATORS
SIZE
CODE IDENT NO
13160
DWG NO
SK003921
REV
B
SCALE
WEIGHT
SHEET 1 OF
H
13160
130811-2
L-11

REMOTE UNIT INTERCONNECT CABLE(S) PIN OUT

CONNECTOR: DD(XX) - 50S W/ DD-24661 CLAMP

CABLE: HEWLETT PACKARD P/N 5040-7860

CONNECTOR PIN NUMBER	WIRE COLOR	SIGNAL NAME
1	WH-BK-GN	RU(1 OR 2) VØA
2	WH-YL-GY	VØB
3	WH-YL-VIO	VØC
4	WH-YL-BU	V AVG DC
5	WH-YL-GN	IØA
6	WH-OR-VIO	IØB
7	WH-OR-BU	IØC
8	WH-OR-GN	IAVG DC
9	WH-OR-YL	PØA
10	WH-VIO	PØB
11	WH-BU	PØC
12	WH-GN	PTOTAL
13	WH-YL	LOAD P TOTAL
14	WH-OR	RU(1 OR 2) PHASE BIAS
15	WH-RD	RU(1 OR 2) AMPL BIAS
16	WH-BN	NOT USED
17	WH-BK	NOT USED
18	WH *	CONT OPEN
19	WH-GY *	CONT CLOSE
20	WH-BK-BN*	-15VDC
21	WH-BK-RD*	+15VDC
22	WH-RD-VIO	RU(1 OR 2) RØA
23	WH-RD-GY	RØB
24	WH-BK-OR	RØC
25	OUTER BARE WIRE	SIGNAL COMMON (J10)

* INDICATES WIRE LOCATED INSIDE INNER SHIELD

CONNECTOR PIN NUMBER	WIRE COLOR	SIGNAL NAME	
26	WH-BK-BU	RU(1or2) UNDER FREQ	
27	WH-RD-BU	OVER FREQ	
28	WH-RD-GN	UNDER VOLTAGE	
29	WH-RD-YL	OVER VOLTAGE	
30	WH-RD-OR	MISSING PHASE	
31	WH-BN-GN	REVERSE PHASE	
32	WH-BN-YL	50HZ	
33	WH-BN-OR	60HZ	
34	WH-BN-RD	400HZ	
35	VIO	CONT CLOSED COMMANDED	
36	BU	CONT CLOSED EXECUTED	
37	GN	CONT CLOSED OVERRIDEN	
38	YL	NOT USED	
39	OR	NOT USED	
40	RD	EXTRA	J10 - 15 or 33
41	BN	EXTRA	J10 - 16 or 34
42	BK	EXTRA	J10 - 17 or 35
43	INNER BARE WIRE	PWR COMMON (J11)	
44	GY*	EXTRA	J11 - 4 or 16
45	WH-BK-GY*	EXTRA.	J11 - 5 or 17
46	WH-BN-GY*	EXTRA.	J11 - 6 or 18
47	WH-BN-BU	REMOTE/LOCAL (J09)	
48	WH-BN-VIO	EXTRA	J11 - 3 or 15
49	WH-BK-YL	SIGNAL COMMON (J09)	
50	WH-BK-VIO	PWR COMMON (J09)	

REV A 12-NOV-1981 G.H.B. RENAME 16, 17, 38, 39

Unico Electronics

RU1 & RU2 REMOTE CABLES

G.H.B. 11/80

G.H. Courts 11/80

C 13160 SK003922 A

SHEET 1 OF 1

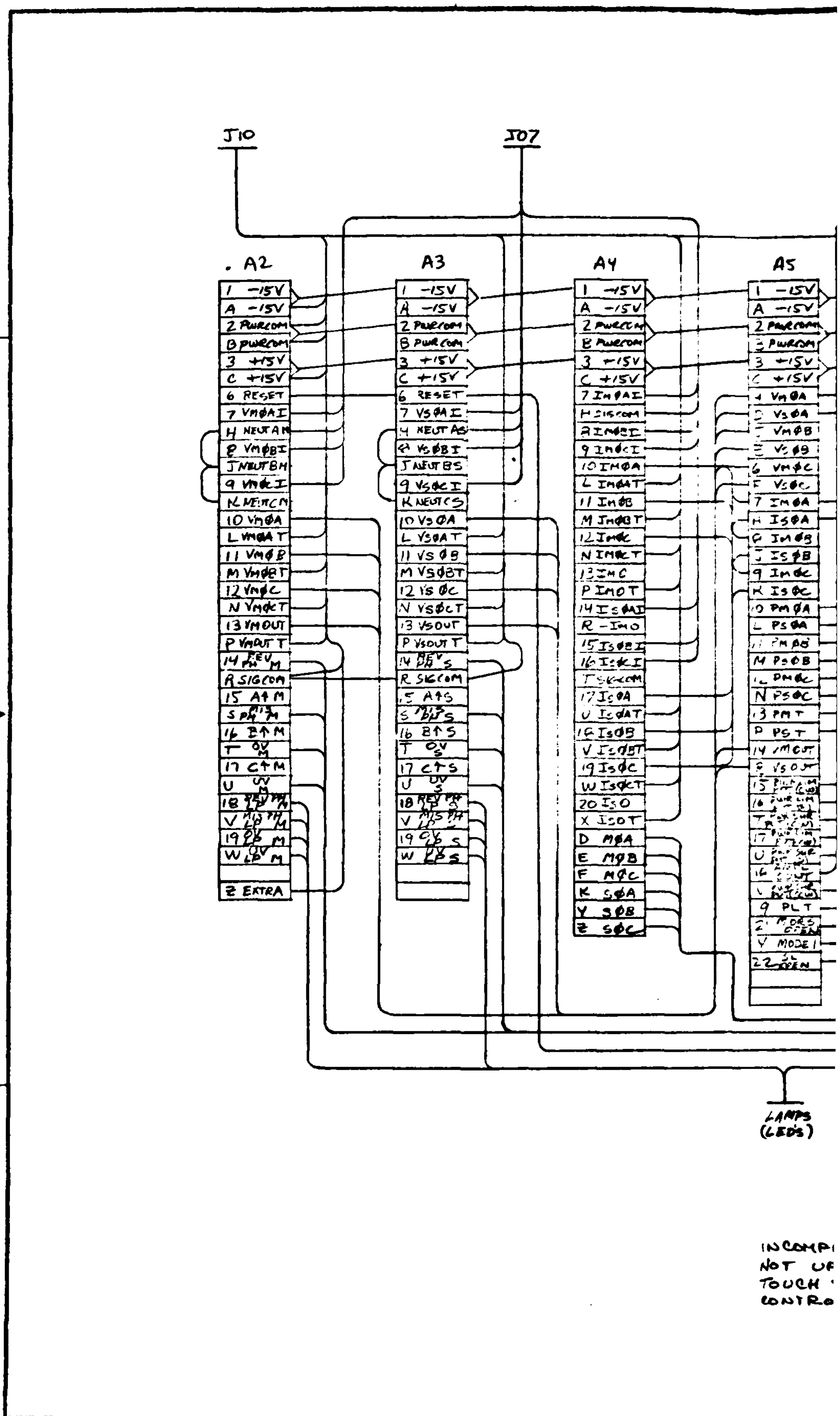
4 ABCDEFHJKLMN PRSTUVWXYZ 3

D

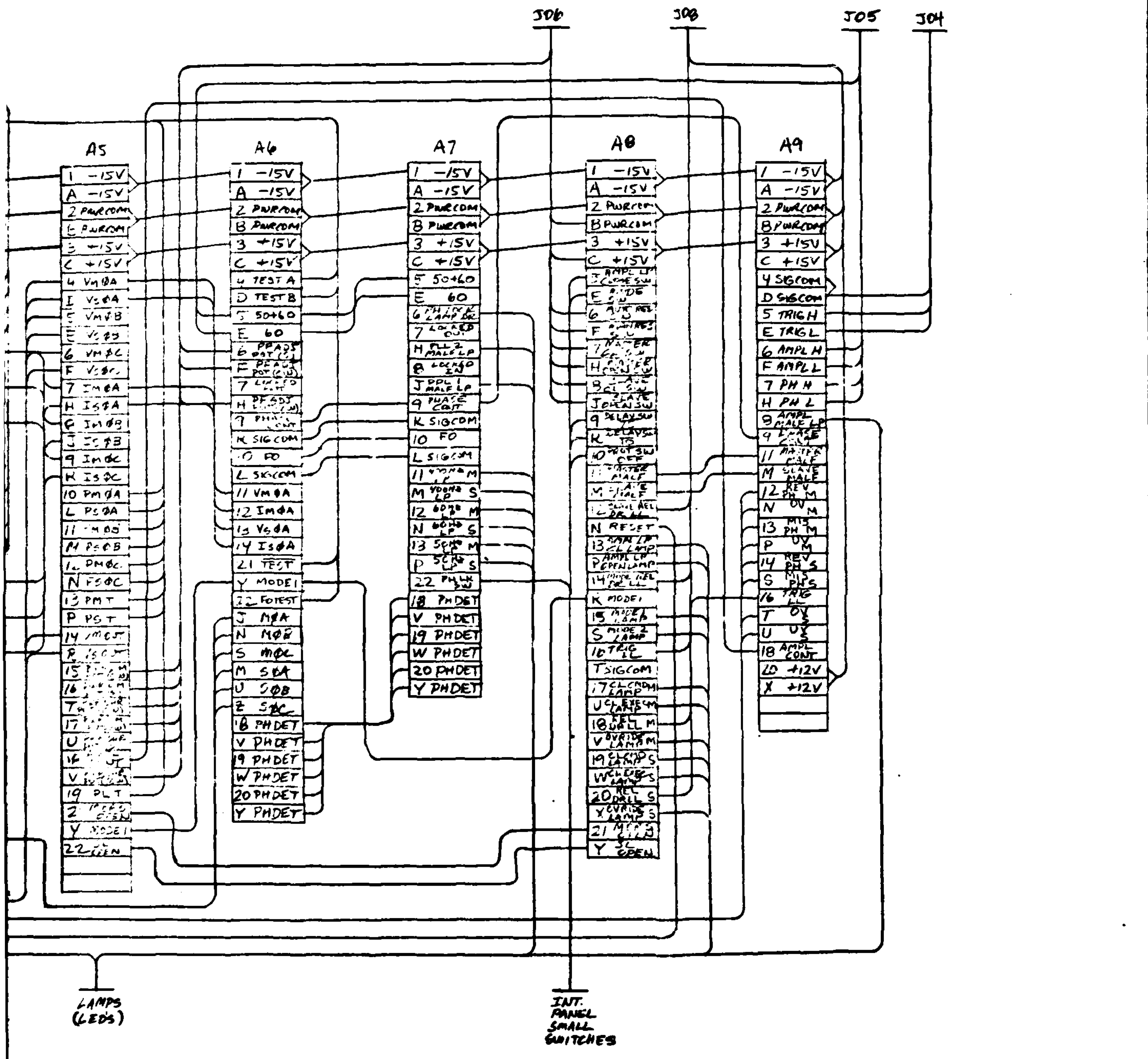
C

B

A



3 2 1

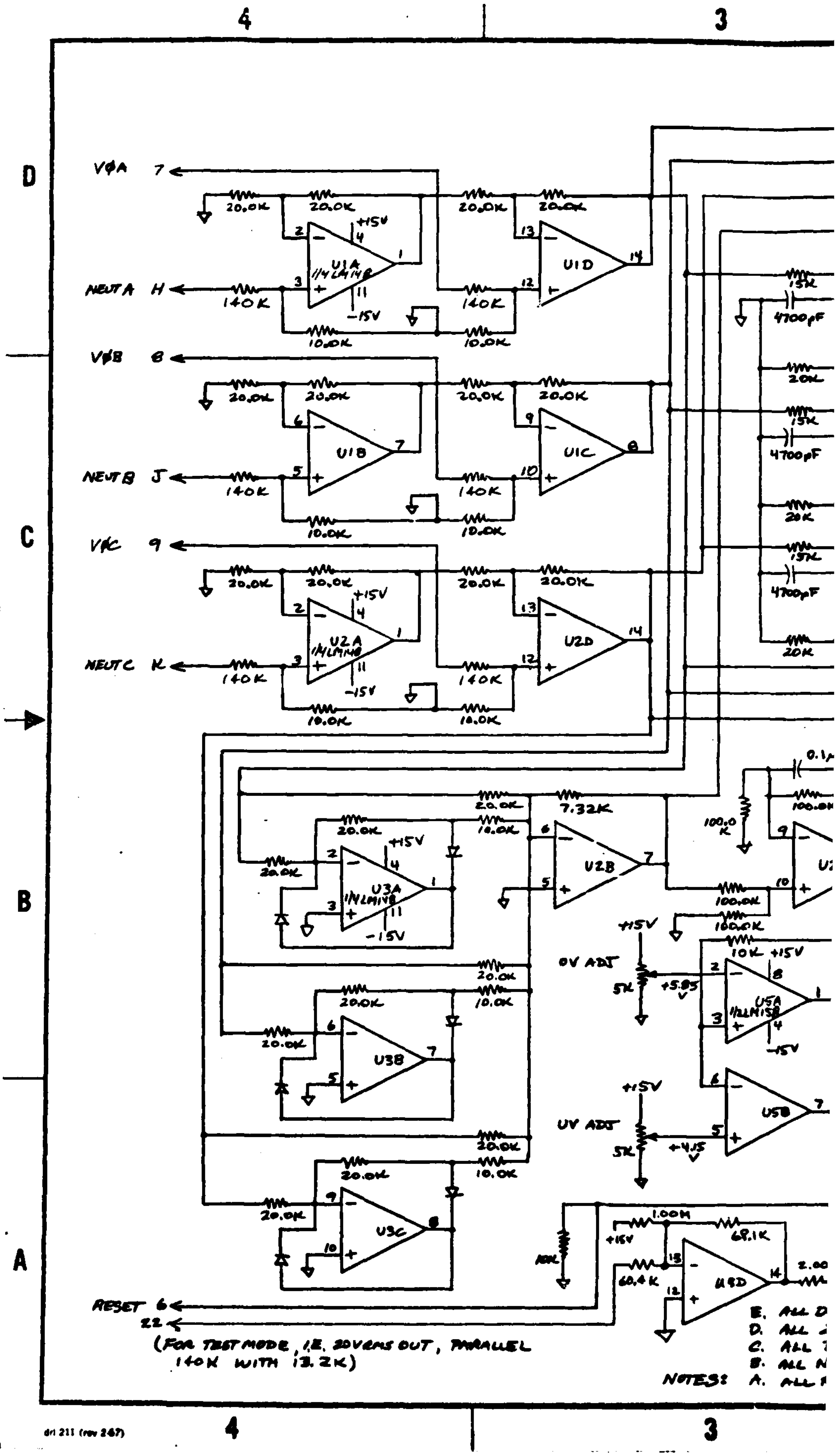


09-28-82 JRC REV B
01-27-81 G.H.B. REV A

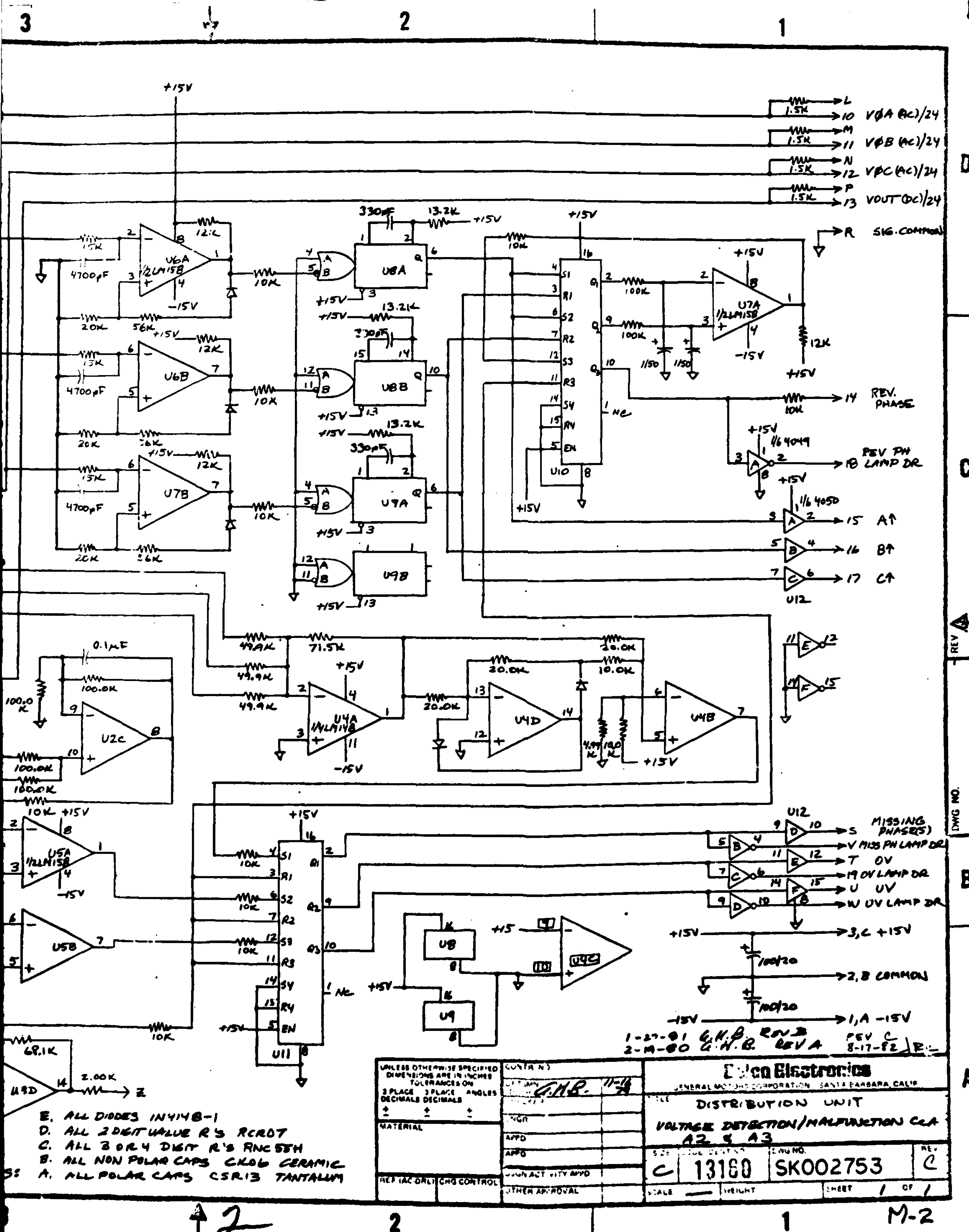
INCOMPLETE DRAWING. NOT UPDATED TO SHOW TOUCH SCREEN CRT CONTROLLER MODIFICATIONS.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO.	Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
MATERIAL	DRAWN G.H.B. 3-18-80	TITLE DISTRIBUTION UNIT WIRING DIAGRAM
	CHECKER	
	ENGR G.H. Barrett 3-18-80	
	APPD	SIZE C CODE IDENT NO 13180 DWG NO. SK002749 REV B
REF (AC ORL) CHG CONTROL	DESIGN ACTIVITY APPD	
	OTHER APPROVAL	SCALE — WEIGHT SHEET 1 OF

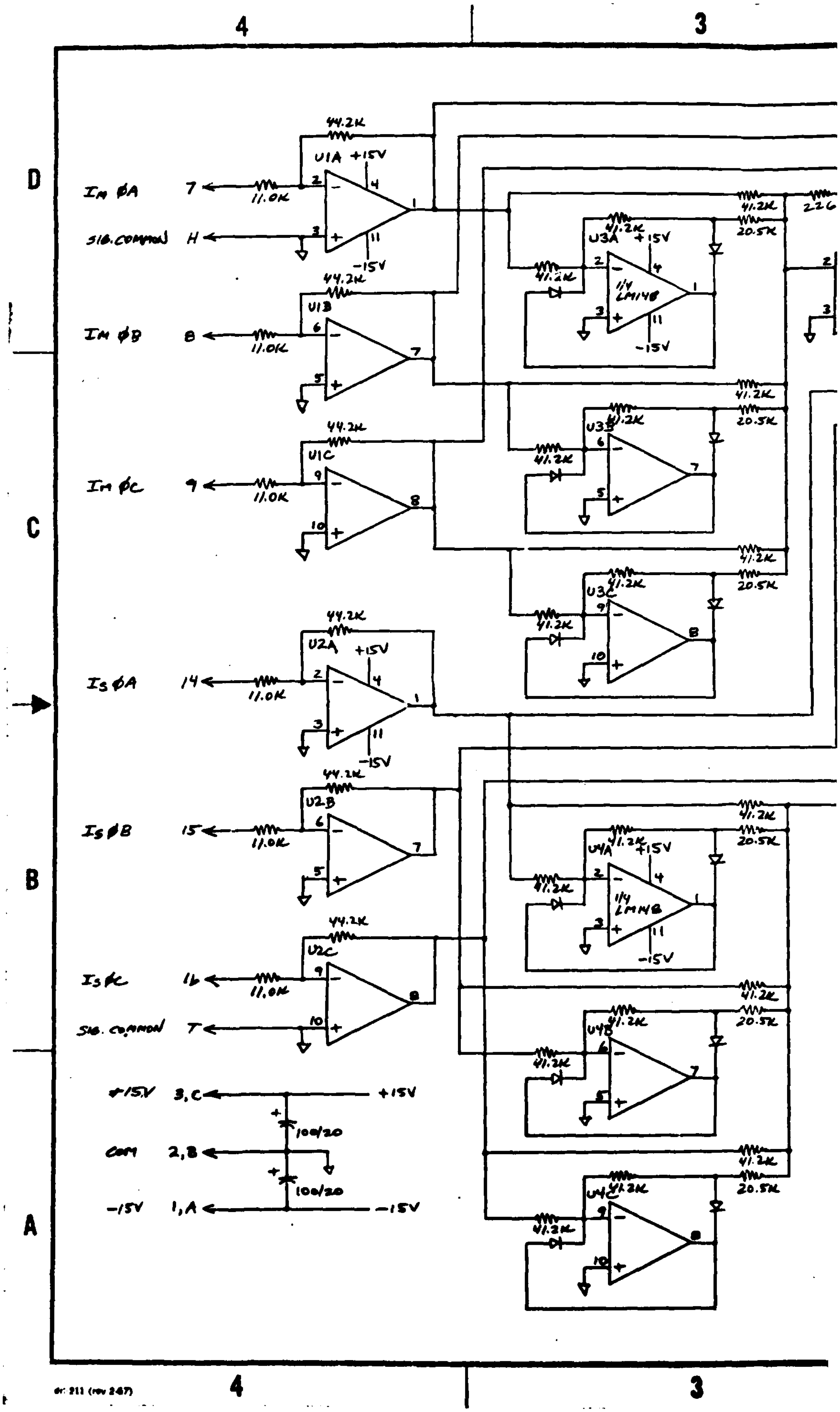
2 1 M-1



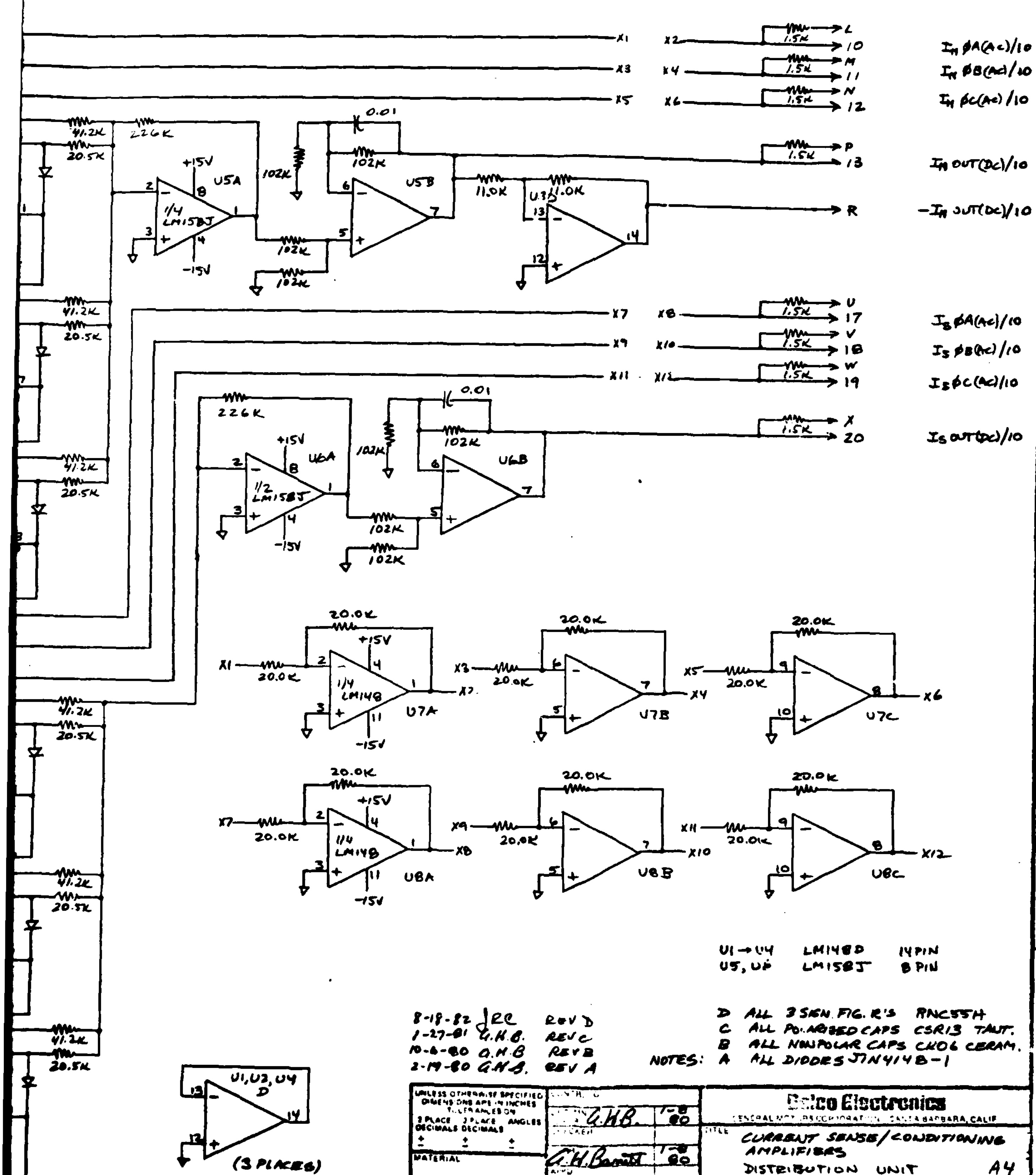
4
3
D
C
B
A
VØA 7
NEUT A H
VØB 8
NEUT B J
VØC 9
NEUT C K
RESET 6
22
(FOR TEST MODE, I.E. 20VRMS OUT, PARALLEL 140K WITH 13.2K)
OV ADJ
UV ADJ
NOTES:



VØA (AC)/24
VØB (AC)/24
VØC (AC)/24
VOUT (DC)/24
SIG. COMMON
REV. PHASE
REV PH LAMP DR
MISSING PHASE(S)
MISS PH LAMP DR
OV
OV LAMP DR
UV
UV LAMP DR
3,C +15V
2,8 COMMON
1,A -15V
1-27-81 G.H.B. REV B
2-14-80 G.H.B. REV A
REV C 8-17-82
E. ALL DIODES IN4148-1
D. ALL 2 DIGIT VALUE R'S RCR07
C. ALL 3 OR 4 DIGIT R'S RNC55H
B. ALL NON POLAR CAPS CK06 CERAMIC
A. ALL POLAR CAPS CSR13 TANTALUM
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
2 PLACE DECIMALS
3 PLACE DECIMALS
ANGLES
MATERIAL
CONTR NO
ENGR
APPD
OTHER APPROVAL
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
DISTRIBUTION UNIT
VOLTAGE DETECTION/MALFUNCTION CCA
A2 & A3
C
13160
SK002753
C
SHEET 1 OF 1
M-2



4
3
D
C
B
A
Im ØA
7
11.0K
44.2K
U1A +15V
SIG. COMMON
H
-15V
U1B
Im ØB
8
U1C
Im ØC
9
U2A
Is ØA
14
U2B
Is ØB
15
U2C
Is ØC
16
SIG. COMMON
T
+15V
3,C
COM
2,B
-15V
1,A
100/20
41.2K
20.5K
U3A
U3B
U3C
U4A
U4B
U4C
1/4 LM148
226



8-18-82 JRC REV D
1-27-81 G.H.B. REV C
10-6-80 G.H.B REV B
2-19-80 G.H.B. REV A

NOTES:
D ALL 3 SIGN. FIG. R'S RNC55H
C ALL POLARIZED CAPS CSR13 TANT.
B ALL NONPOLAR CAPS CK06 CERAM.
A ALL DIODES JTN4148-1

Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

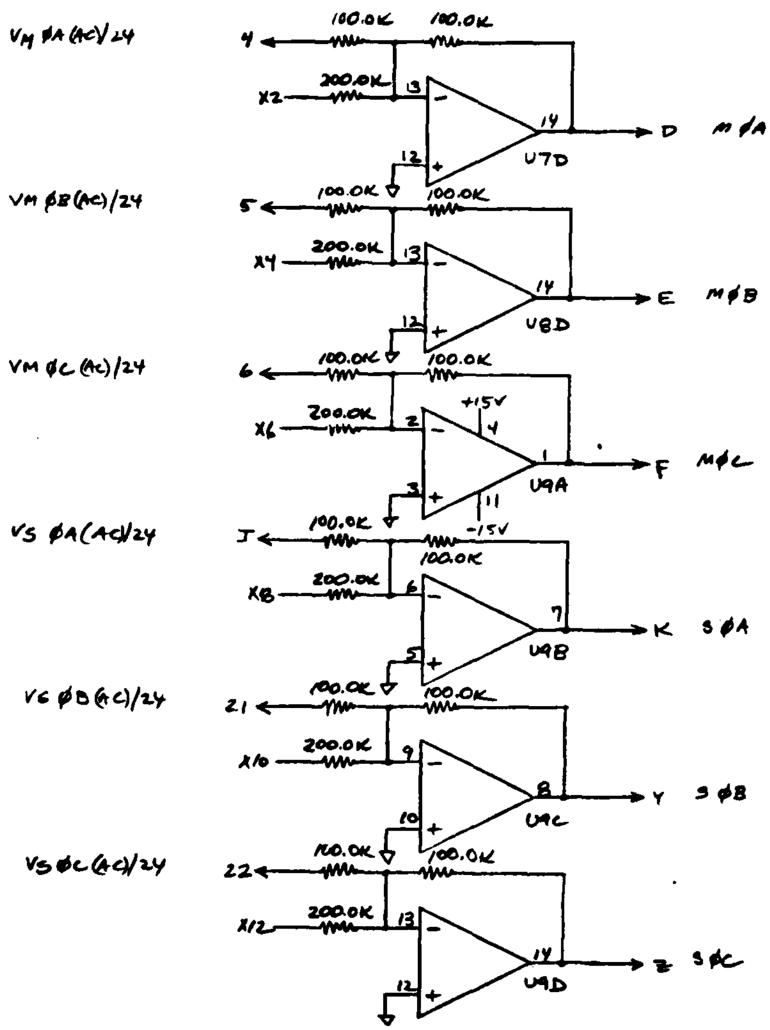
TITLE: CURRENT SENSE/CONDITIONING AMPLIFIERS DISTRIBUTION UNIT A4

DRAWN G.H.B. 1-8-80
G.H. Barrett 1-8-80

SIZE C | CODE IDENT NO 13160 | DWG NO SK002754 | REV D

SHEET 1 OF 2

M-3a


VM ØA (AC)/24
4
100.0K
100.0K
X2
200.0K
13
14
12
U7D
D
MØA
VM ØB (AC)/24
5
100.0K
100.0K
X4
200.0K
13
14
12
U8D
E
MØB
VM ØC (AC)/24
6
100.0K
100.0K
X6
200.0K
+15V
2
4
1
3
11
-15V
U9A
F
MØC
VS ØA (AC)/24
J
100.0K
100.0K
X8
200.0K
6
7
5
U9B
K
SØA
VS ØB (AC)/24
21
100.0K
100.0K
X10
200.0K
9
8
10
U9C
Y
SØB
VS ØC (AC)/24
22
100.0K
100.0K
X12
200.0K
13
14
12
U9D
Z
SØC

4 3

D

C

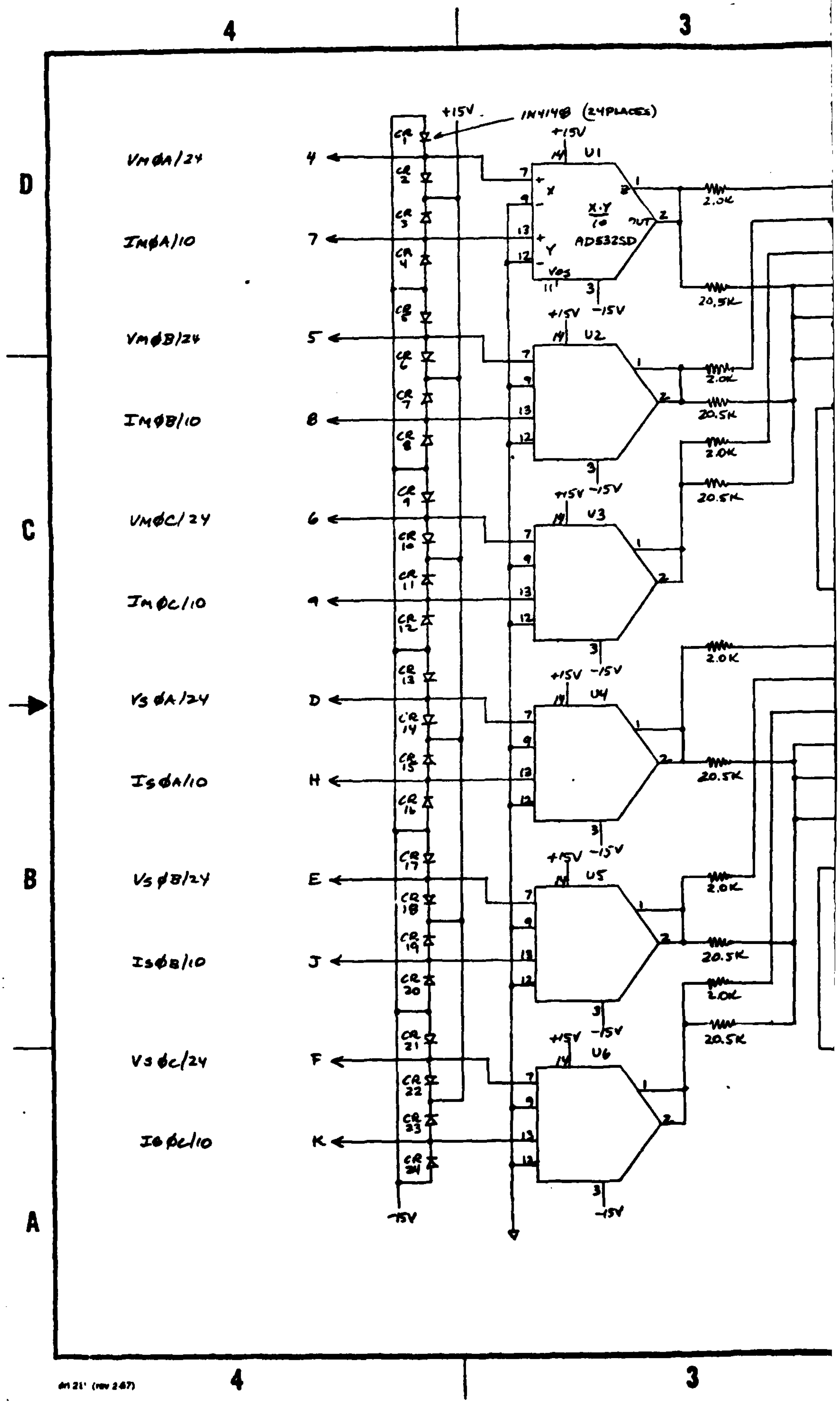
B

A

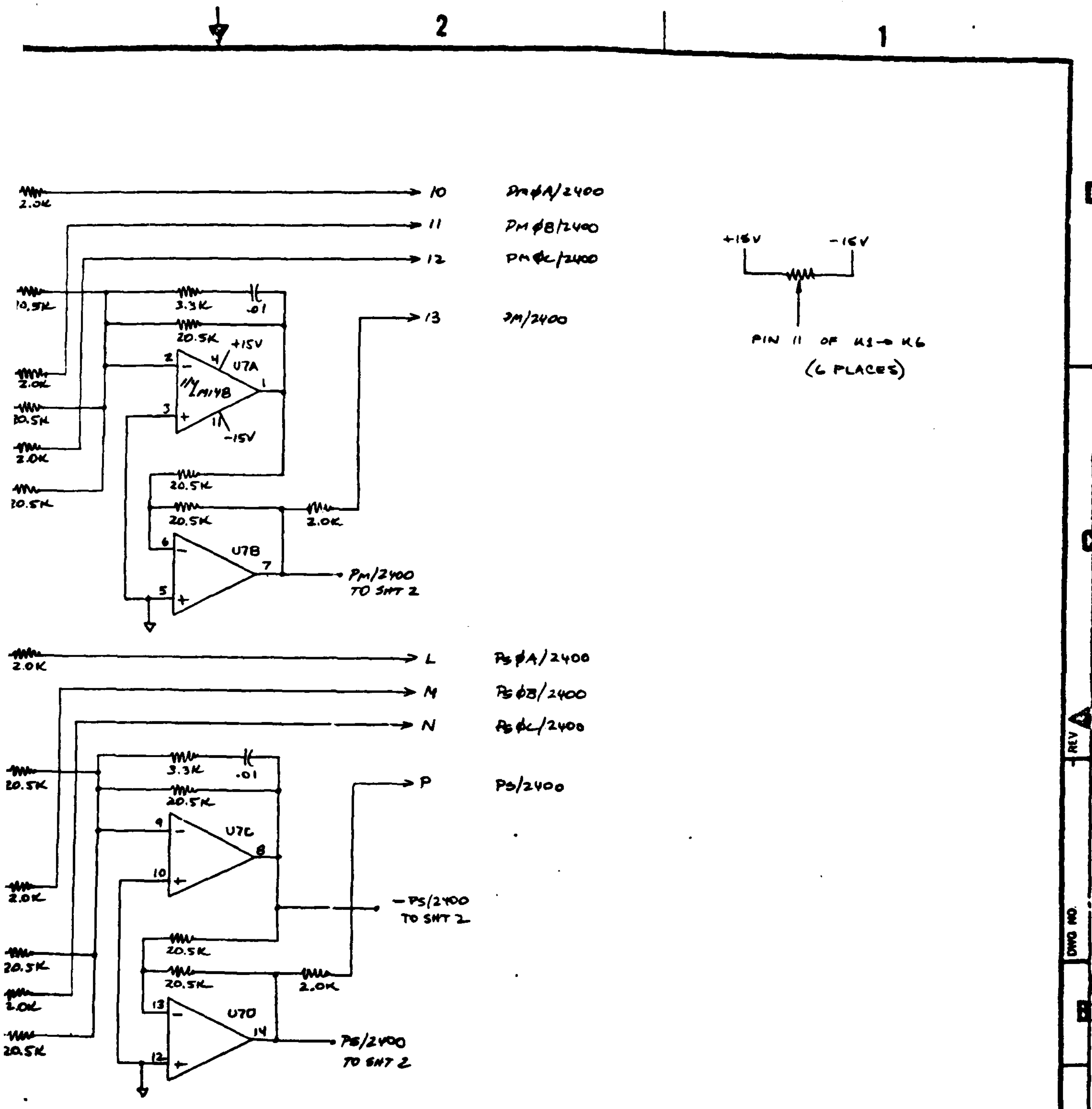
4 3

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO		**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	DRAWN G.K.B.	10-6-80	TITLE CURRENT SENSE/CONDITIONING AMPLIFIERS DISTRIBUTION UNIT A4
	CHECKER		
MATERIAL	ENGR R.K. Barrett	10-6-80	
	APPD		
	APPD		SIZE C · CODE IDENT NO 13160 · DWG NO. SK002754 · REV D
REF (AC ONLY) · CHG CONTROL	DSGN ACTIVITY APPD		
	OTHER APPROVAL		SCALE · WEIGHT · SHEET 2 OF 2

M-3B



4
3
D
C
B
A
IN4148 (24 PLACES)
+15V
-15V
VMØA/24
IMØA/10
VMØB/24
IMØB/10
VMØC/24
IMØC/10
VsØA/24
IsØA/10
VsØB/24
IsØB/10
VsØC/24
IsØC/10
4
7
5
8
6
9
D
H
E
J
F
K
U1
U2
U3
U4
U5
U6
AD532SD
X·Y/10
OUT
2.0K
20.5K



08-17-82 J.R.C REV B
01-27-81 G.H.B. REV A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS 3 PLACE DECIMALS ANGLES ± ± ±

MATERIAL

G.H.B. 2-29-80

G.H. Bassett 2-29-80

APPD

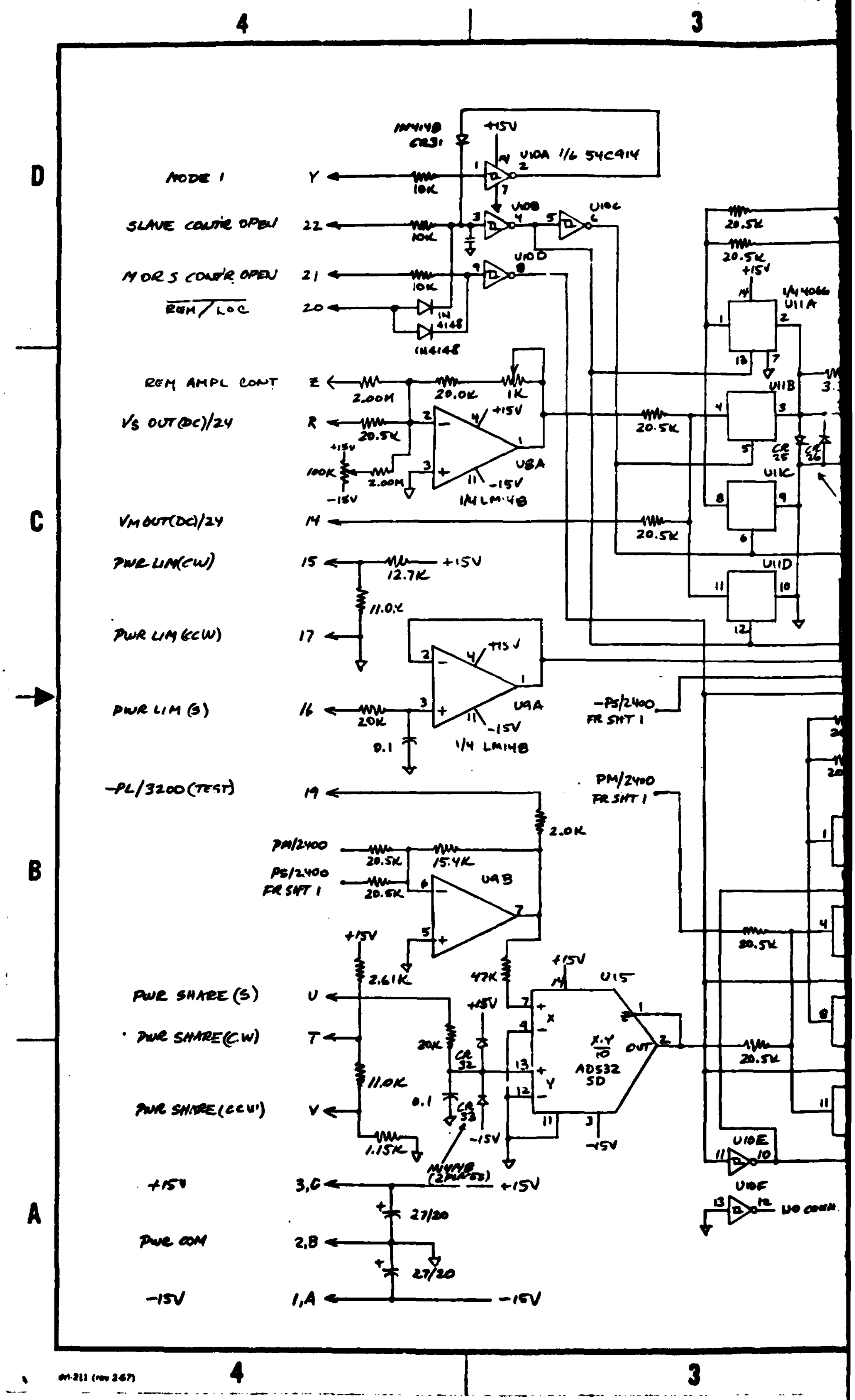
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF

DISTRIBUTION UNIT
AMPLITUDE CONTROL CIRCUITS
45

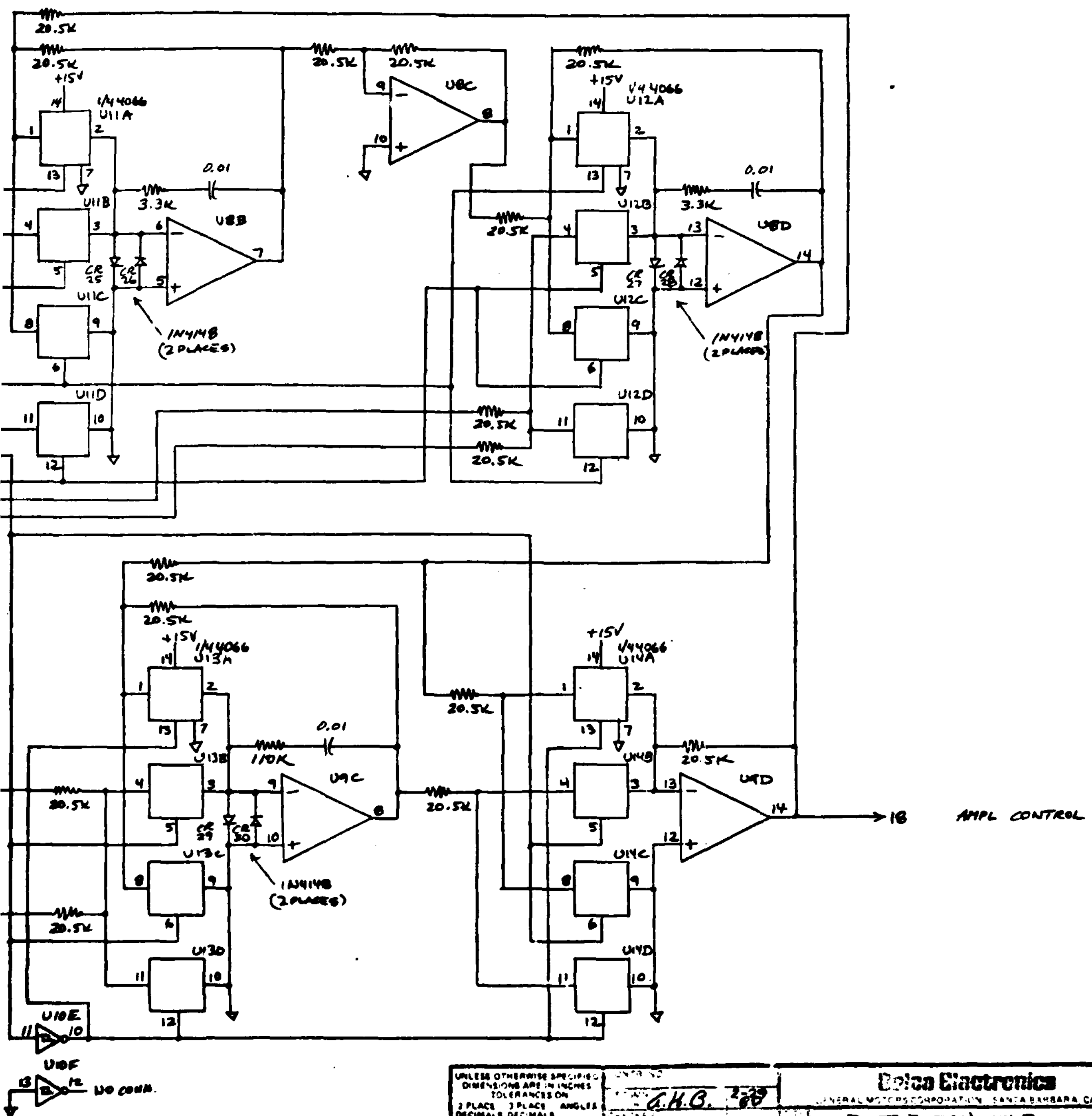
SIZE	CODE IDENT NO	DWG NO.	REV
C	13160	SK002755	B

SCALE — WEIGHT SHEET 1 OF 2

2 2 1 M-4a



MODE 1
SLAVE CONT'R OPEN
M OR S CONT'R OPEN
REM/LOC
REM AMPL CONT
Vs OUT(DC)/24
VM OUT(DC)/24
PWR LIM(CW)
PWR LIM(CCW)
PWR LIM (S)
-PL/3200(TEST)
PM/2400
PS/2400 FR SHT 1
PWR SHARE (S)
PWR SHARE(CW)
PWR SHARE(CCW)
+15V
PWR COM
-15V
U10A 1/6 54C914
1/4 4066
U8A
1/4 LM148
U9A
U9B
U15
AD532 SD
-PS/2400 FR SHT 1
PM/2400 FR SHT 1
U10E
U10F



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±

MATERIAL

DRAWN: G.H.B. 2-29-80
CHECKED: G.H. Barrett 2-29-80

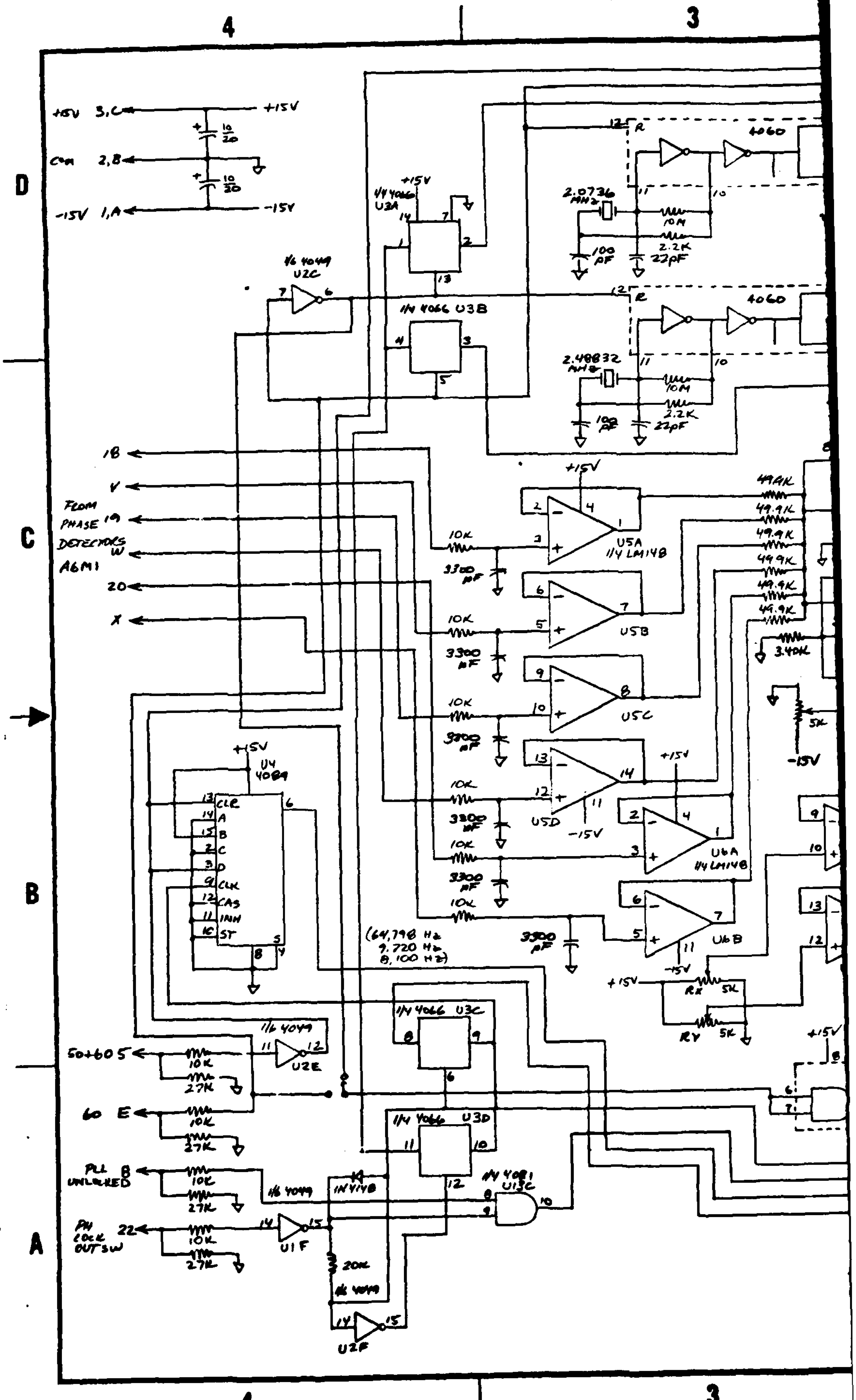
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.

TITLE: DISTRIBUTION UNIT
AMPLITUDE CONTROL CIRCUITS
A5

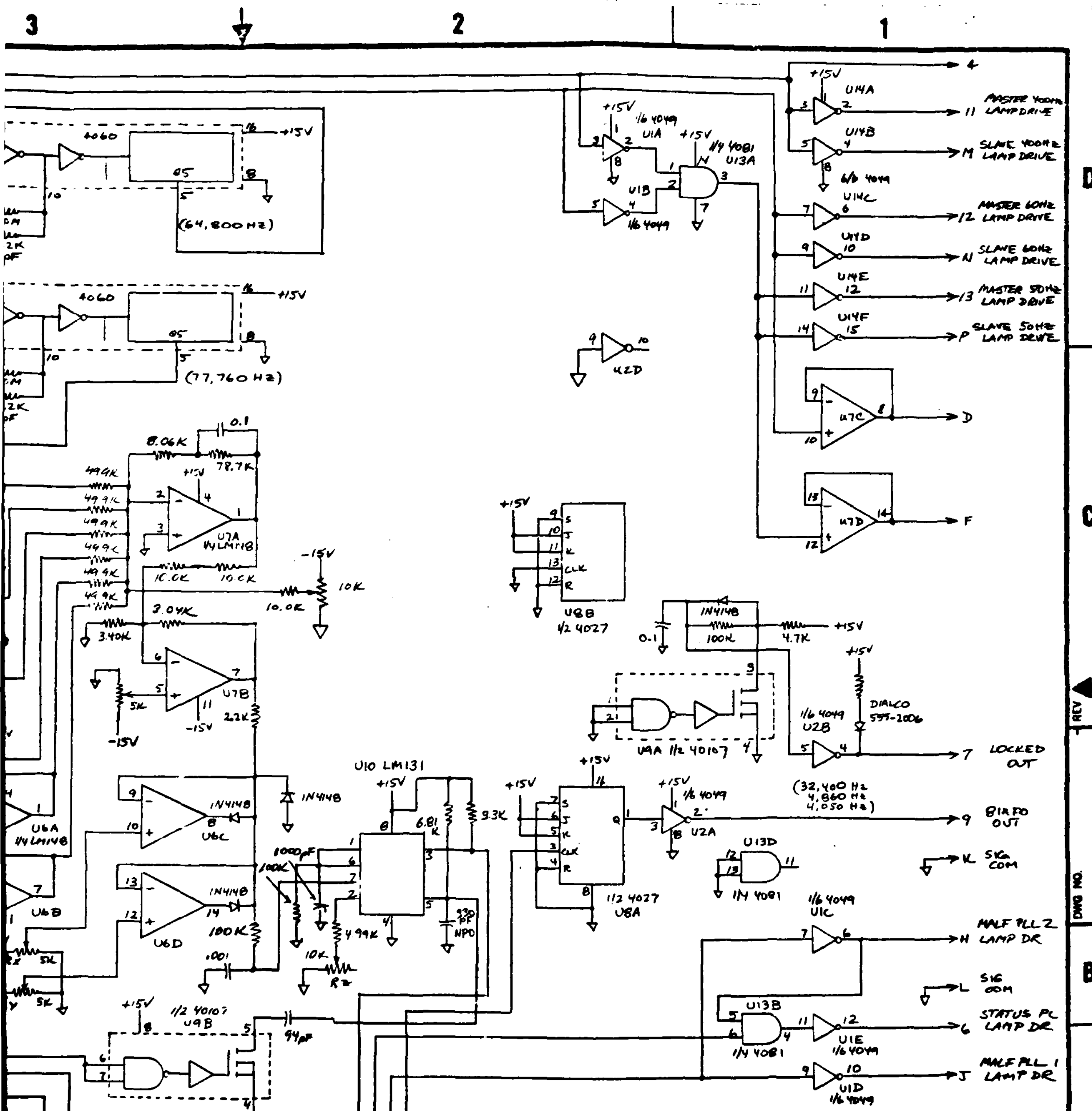
SIZE	CODE IDENT NO.	DWG NO.	REV
C	13160	SK002755	B

SCALE — WEIGHT SHEET 2 OF 2

M-4B



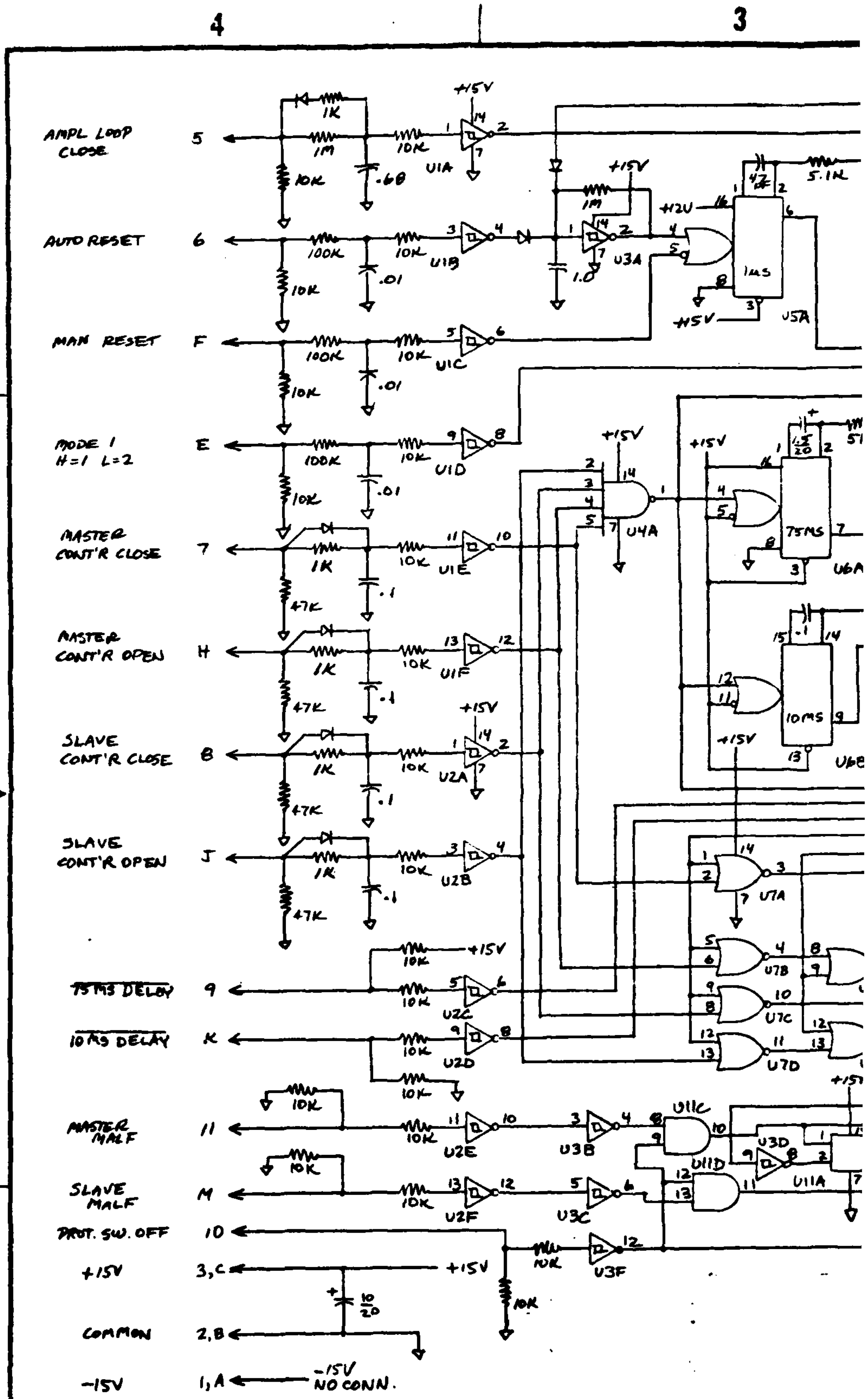
01-211 (rev 2-87)



REV B 8-17-82 JEL

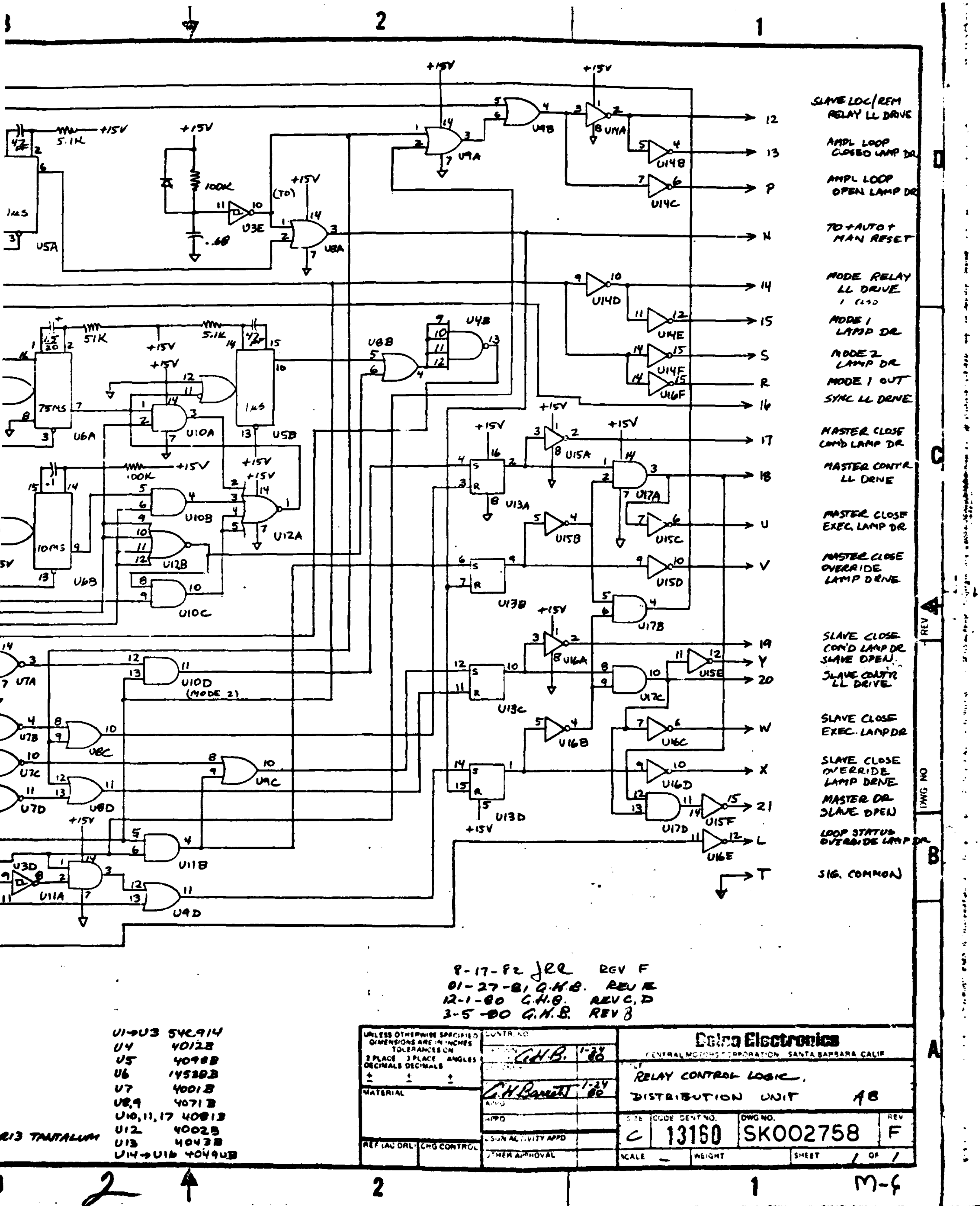
REV + NEW VELLUM G.H.B. 10-6-80

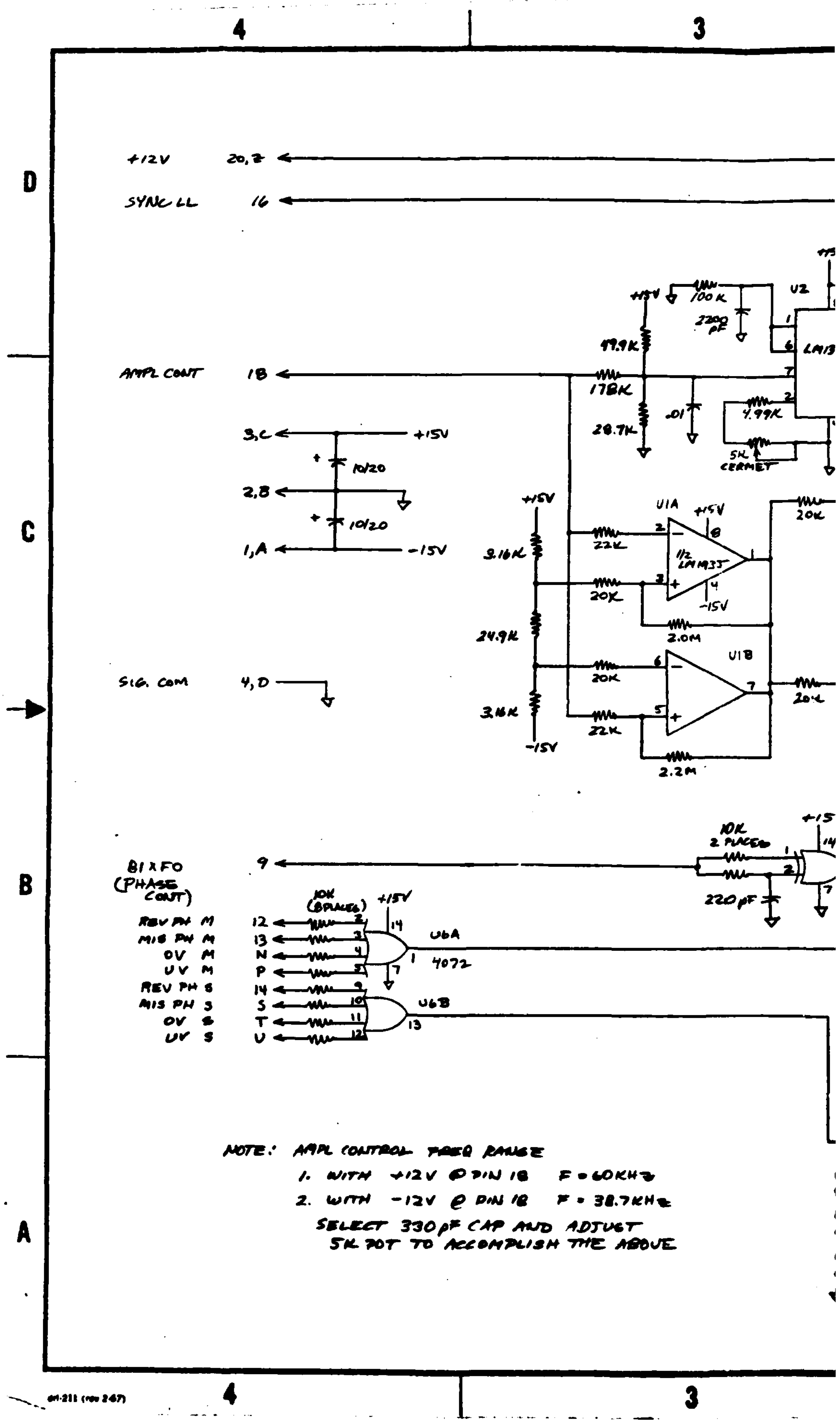
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO	**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
MATERIAL	DRAWN G.H.B. 10-6-80	TITLE PLL & 81xFO GENERATOR, DISTRIBUTION UNIT A7
	CHECKED G.H. Garrett 10-6-80	SIZE C · CODE IDENT NO 13160 · DWG NO SK002757 · REV B
REF (AC-ORL) · CHG CONTROL	APPD · APPD · DSGN ACTIVITY APPD · OTHER APPROVAL	SCALE · WEIGHT · SHEET 1 OF 1



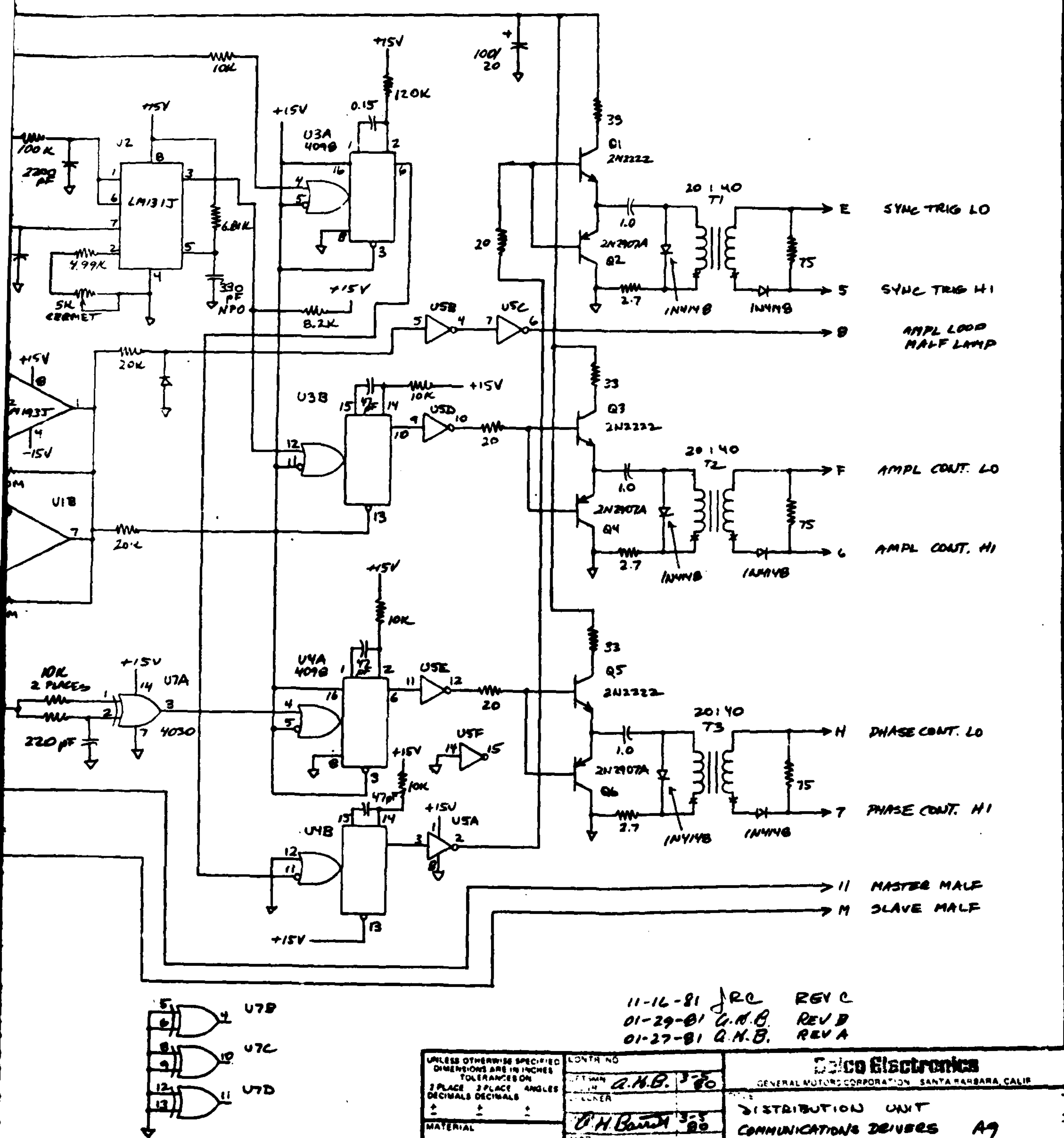
C. ALL DIODES 1N4148-1
B. ALL RESISTORS RCR07
NOTES: A. ALL CAPS CK05 OR CK06 CERAMIC, EXCEPT POLARIZED CSR13 TANTALUM

drl 211 (rev 2-67)


SLAVE LOC/REM RELAY LL DRIVE
AMPL LOOP CLOSED LAMP DR
AMPL LOOP OPEN LAMP DR
TO + AUTO + MAN RESET
MODE RELAY LL DRIVE
MODE 1 LAMP DR
MODE 2 LAMP DR
MODE 1 OUT
SYNC LL DRIVE
MASTER CLOSE COMD LAMP DR
MASTER CONT'R LL DRIVE
MASTER CLOSE EXEC LAMP DR
MASTER CLOSE OVERRIDE LAMP DRIVE
SLAVE CLOSE CON'D LAMP DR
SLAVE OPEN
SLAVE CONTR LL DRIVE
SLAVE CLOSE EXEC. LAMP DR
SLAVE CLOSE OVERRIDE LAMP DRIVE
MASTER OR SLAVE OPEN
LOOP STATUS OVERRIDE LAMP DR
SIG. COMMON
8-17-82 JRR REV F
01-27-81 G.H.B. REV E
12-1-80 G.H.B. REV C, D
3-5-80 G.H.B. REV B
U1→U3 54C914
U4 4012B
U5 4098B
U6 14528B
U7 4001B
U8,9 4071B
U10,11,17 4081B
U12 4002B
U13 4043B
U14→U16 4049UB
C13 TANTALUM
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA CALIF
RELAY CONTROL LOGIC, DISTRIBUTION UNIT A8
SIZE C CODE IDENT NO. 13160 DWG NO. SK002758 REV F
SHEET 1 OF 1
M-6



DH-211 (rev 2-67)



11-16-81 JRC REV C
01-29-81 G.H.B. REV B
01-27-81 G.H.B. REV A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS 3 PLACE DECIMALS ANGLES ± ± ±

MATERIAL

CONTR NO

DRAWN G.H.B. 3-5-80

CHECKER G.H. Barrett 3-5-80

APPD

APPD

CONTRACT ACTIVITY APPD

OTHER APPROVAL

REF (AC-CALC) CHG CONTROL

Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF

DISTRIBUTION UNIT
COMMUNICATIONS DRIVERS A9

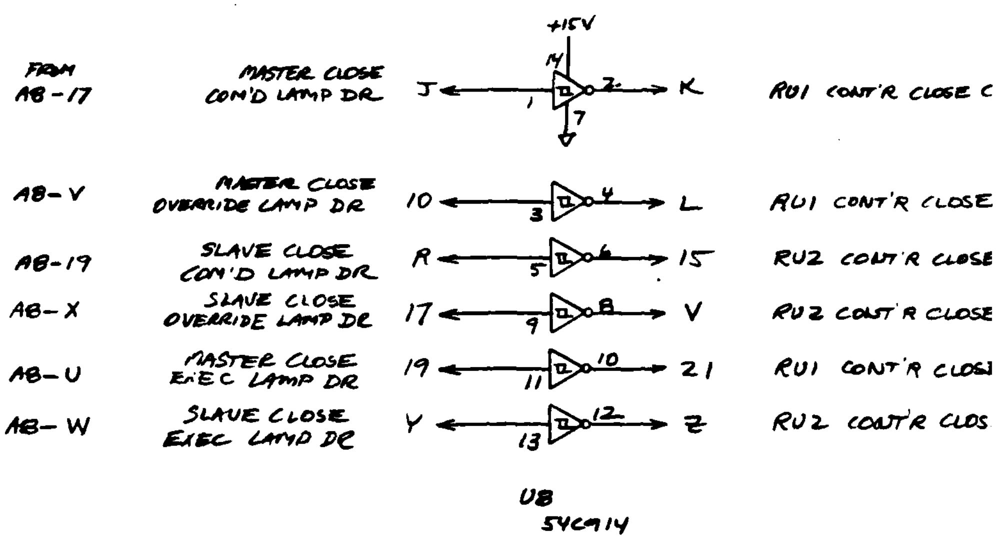
SIZE	CODE IDENT NO	DWG NO	REV
C	13160	SK002759	C

SCALE — WEIGHT SHEET 1 OF 2

M-7A

4 3

D



C

B

A

DH 211 (rev 2-67) 4 3

3 2 1

ONT'R CLOSE COMMANDED

CONT'R CLOSE OVERRIDDEN

CONT'R CLOSE COMMANDED

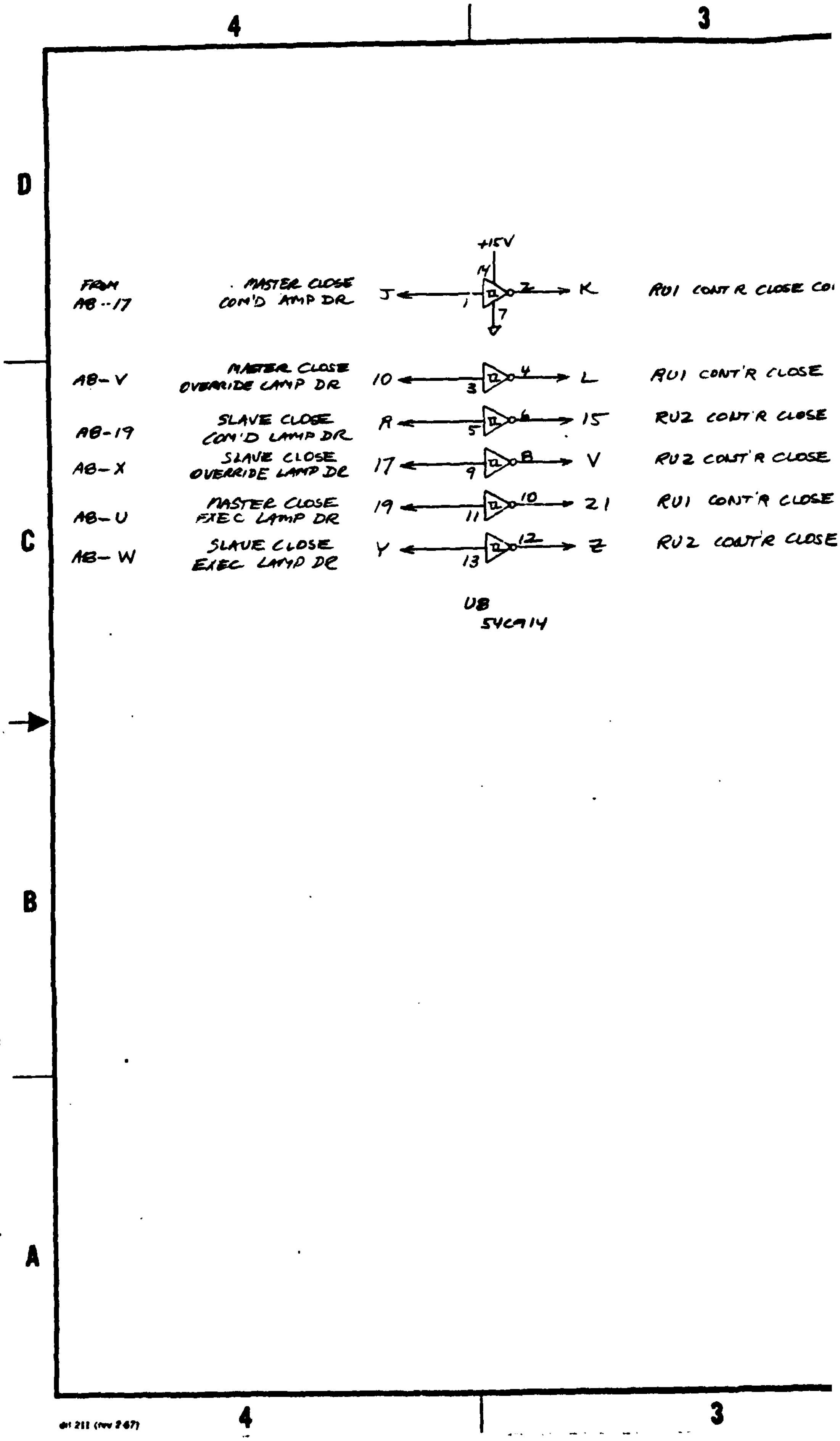
CONT'R CLOSE OVERRIDDEN

CONT'R CLOSE EXECUTED

CONT'R CLOSE EXECUTED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	A.H.B.	16 NOV 81	TITLE DISTRIBUTION UNIT COMMUNICATIONS DRIVERS A9
MATERIAL	A.H. Barrett	16 NOV 81	
	APPD		SIZE C / FSCM IDENT NO 13160 / DWG NO SK002759 / REV C
REL (ACORL) / CHG CONTROL	DSGN ACTIVITY APPD		
	OTHER APPROVAL		SCALE — / WEIGHT / SHEET 2 OF 2

3 42 2 1 M-7B



4
3
D
C
B
A
+15V
FROM
AB-17
MASTER CLOSE
COM'D AMP DR
J
K
RU1 CONT R CLOSE CO
AB-V
MASTER CLOSE
OVERRIDE LAMP DR
10
L
RU1 CONT'R CLOSE
AB-19
SLAVE CLOSE
COM'D LAMP DR
R
15
RU2 CONT'R CLOSE
AB-X
SLAVE CLOSE
OVERRIDE LAMP DR
17
V
RU2 CONT'R CLOSE
AB-U
MASTER CLOSE
EXEC LAMP DR
19
21
RU1 CONT'R CLOSE
AB-W
SLAVE CLOSE
EXEC LAMP DR
Y
Z
RU2 CONT'R CLOSE
U8
54C914

3 2 1

ONT'R CLOSE COMMANDED

CONT'R CLOSE OVERRIDDEN

CONT'R CLOSE COMMANDED

CONT'R CLOSE OVERRIDDEN

CONT'R CLOSE EXECUTED

CONT'R CLOSE EXECUTED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS 3 PLACE DECIMALS ANGLES ± ± ±	G.H.B. 16-NOV-81	Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
MATERIAL	G.H. Barrett 16 NOV 81	DISTRIBUTION UNIT COMMUNICATIONS DRIVERS A9
	APPD	SIZE C · CODE IDENT NO. 13160 · DWG NO. SK002759 · REV C
REF (AC-DRL) · CHG CONTROL	OTHER APPROVAL	SCALE — · WEIGHT · SHEET 2 OF 2

3 2 2 1

M-7B

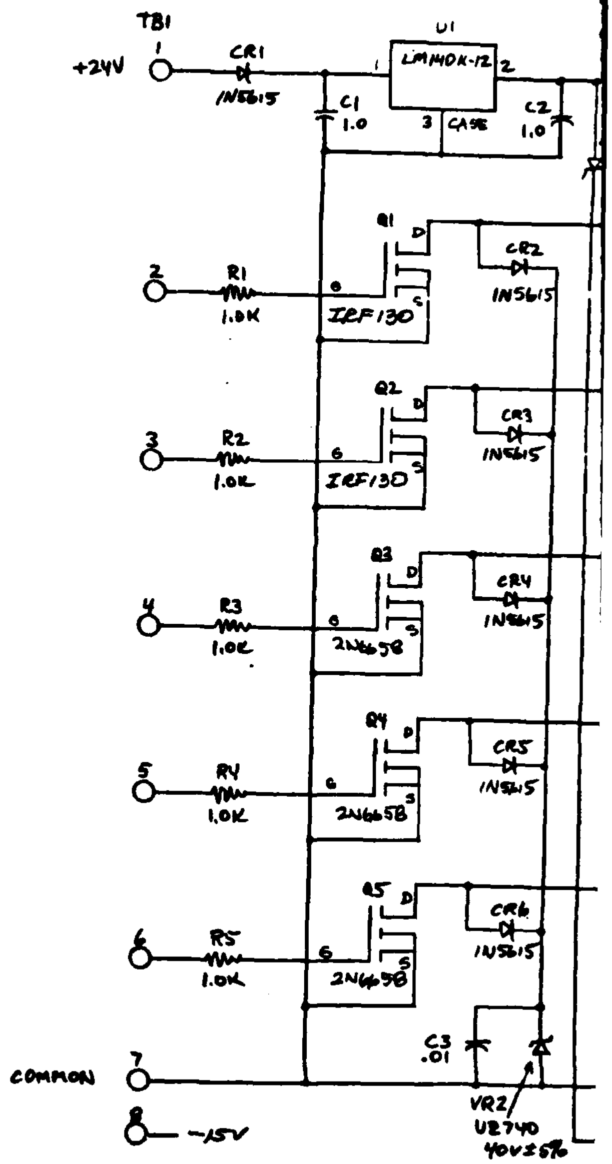
4 3

D

C

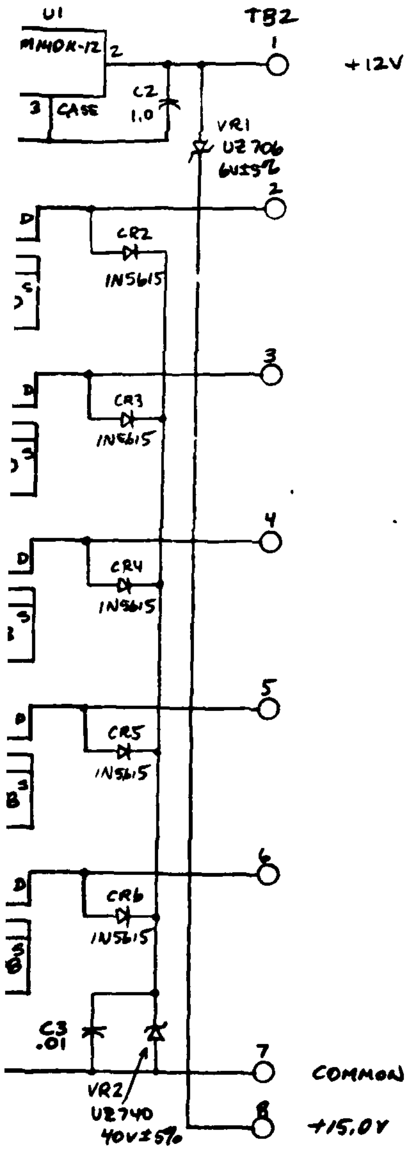
B

A



NOTES:
2. ALL CAPS CK05 OR CK06 CERAMICS
1. ALL RESISTORS RCR07G102JS

4 3

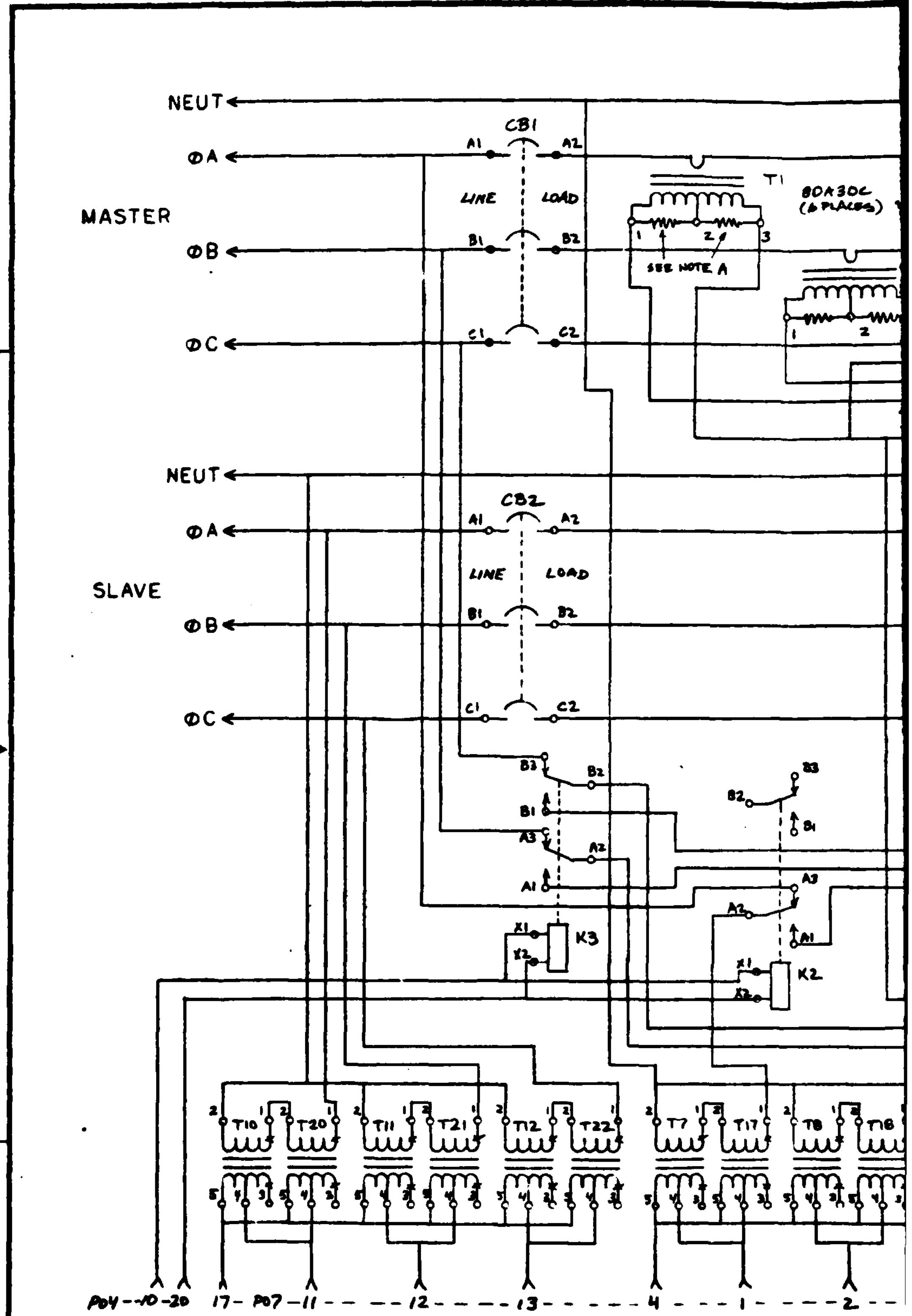


:K06 CERAMICS
76102JS

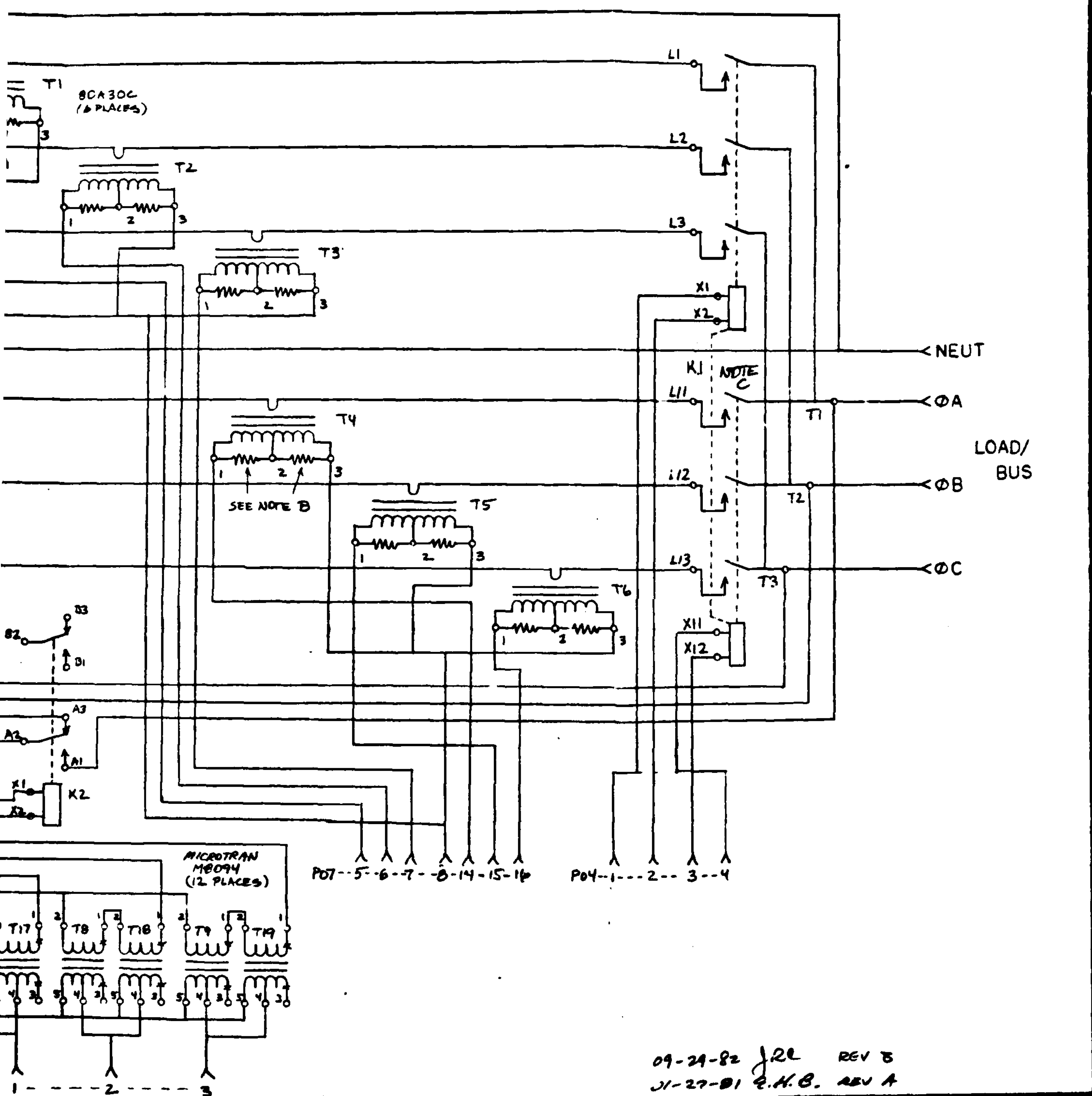
09-29-82 Jee REV B
01-27-81 O.H.B. REV A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO	Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
MATERIAL	DRAWN C.K.B. 2-27-80	TITLE DISTRIBUTION UNIT 12V LAMP SUPPLY AND RELAY DRIVERS AB
	CHECKER C.K.Barrett 2-27-80	
	APPD	SIZE C — CODE IDENT NO 13160 — DWG NO SK002763 — REV B
REF (AC ONLY) / CHG CONTROL	MAIN ACTIVITY APPD / OTHER APPROVAL	SCALE — WEIGHT — SHEET 1 OF 1

3 2 1
2
M-8



NOTE C   K1 HAS MECHANICAL MOD. FOR 6P OPERATION
NOTE B   R   24.9Ω, 1%, 1/8W, RNC60H24R9FM (6 PLACES)
NOTE A   R   24.9Ω, 1%, 1/8W, RNC60H24R9FM (6 PLACES)

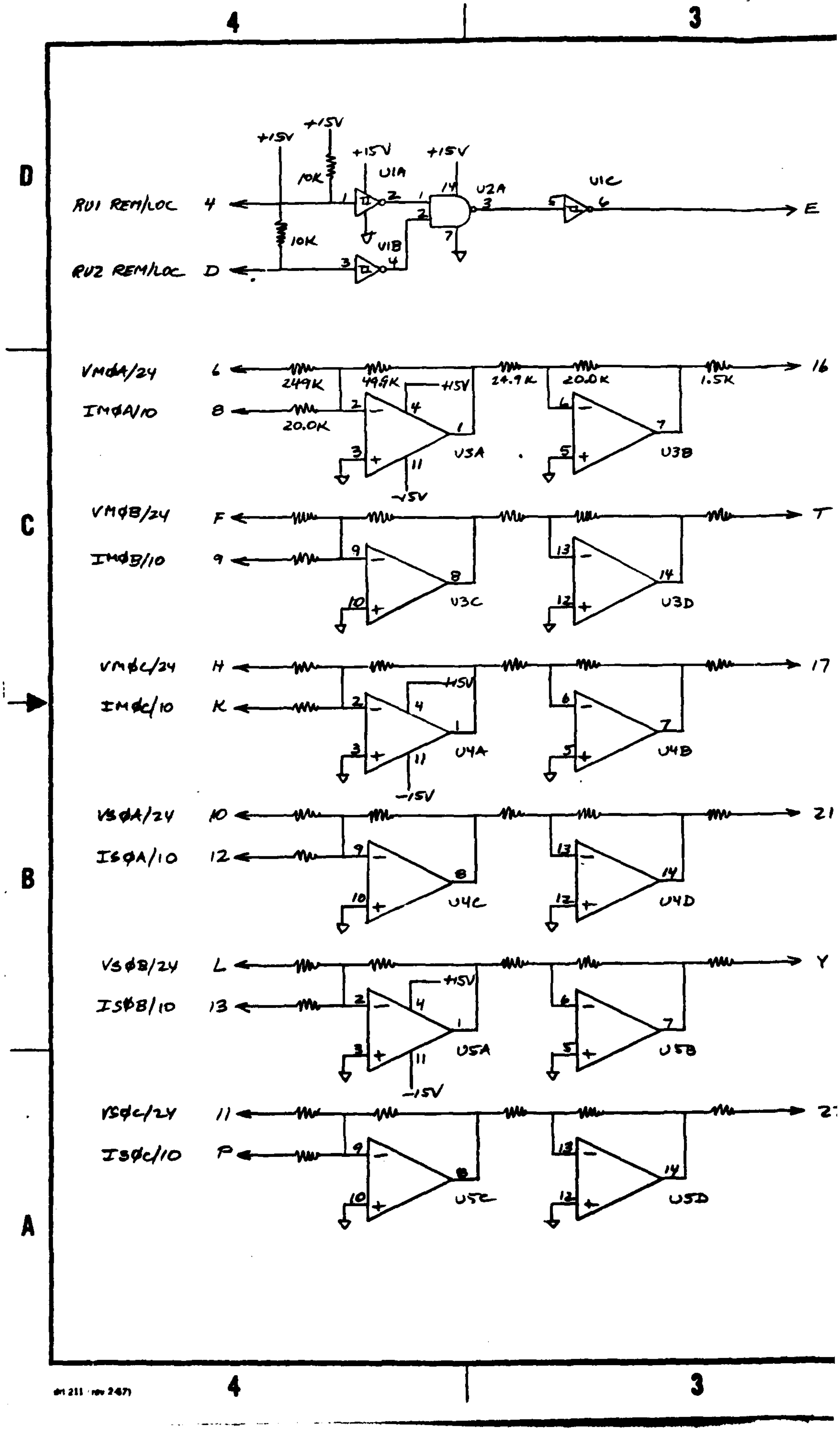


09-29-82 JRL REV B

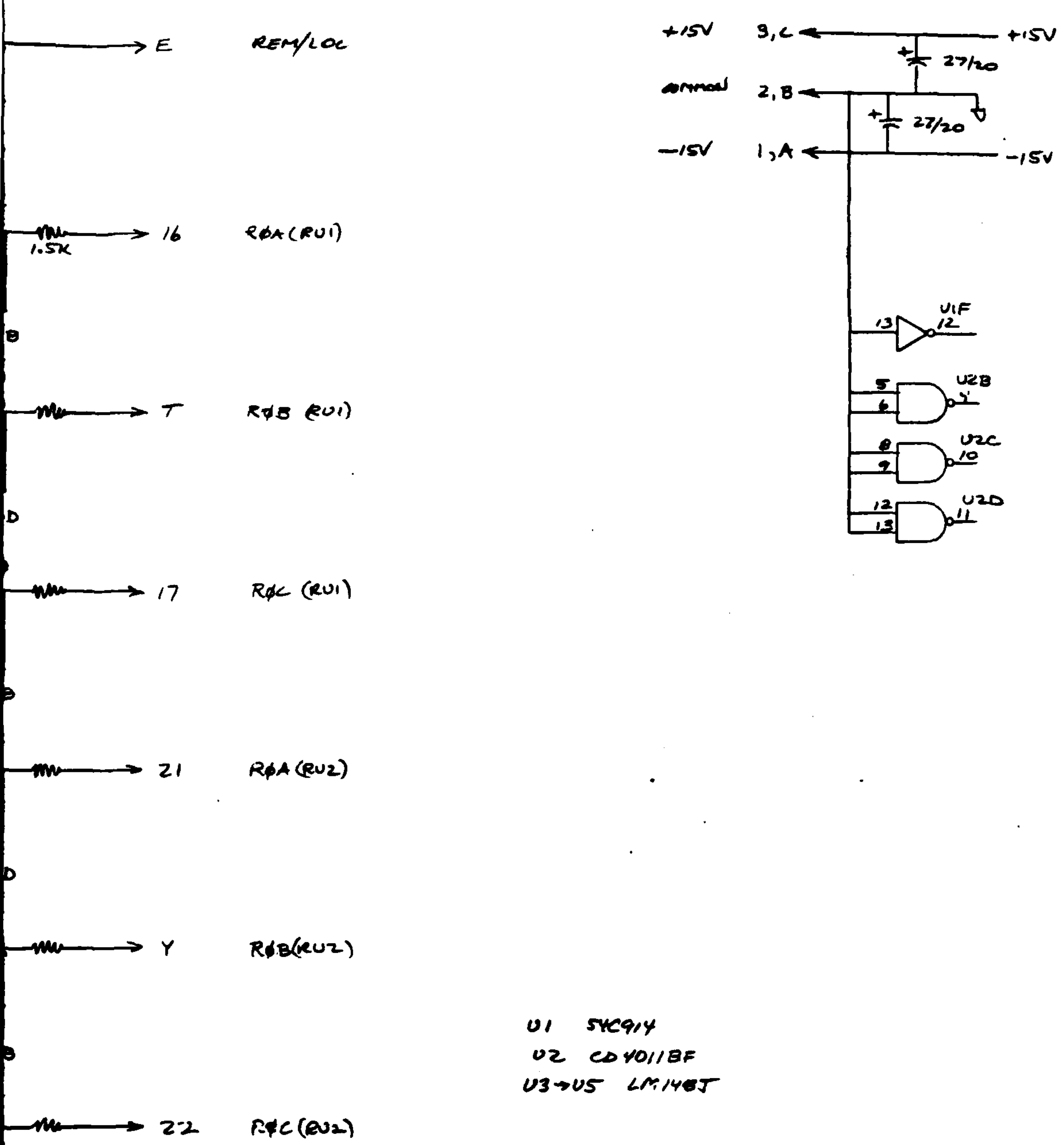
01-27-81 C.H.B. REV A

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO DRAWN C.H.B. 2/25/80	Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
MATERIAL	CHECKED C.H. Barrett 2/25/80 APPD	TITLE DISTRIBUTION UNIT HIGH POWER & SENSE CIRCUITS
REF (AC-DRL) / CHG CONTROL	DSGN ACTIVITY APPD OTHER APPROVAL	SIZE C · CODE IDENT NO 13160 · DWG NO SK002764 · REV B SCALE — · WEIGHT · SHEET 1 OF 1

M-9



dn 211 rev 2/71



U1 54C914
U2 CD4011BF
U3→U5 LM148J

REV B 8-17-82 JRL
REV A ADD SHEET 2 8 DEC 81 G.H.B.

Delco Electronics

DISTRIBUTION UNIT
REM/LOC AND REF PHASE GENERATORS
A6B

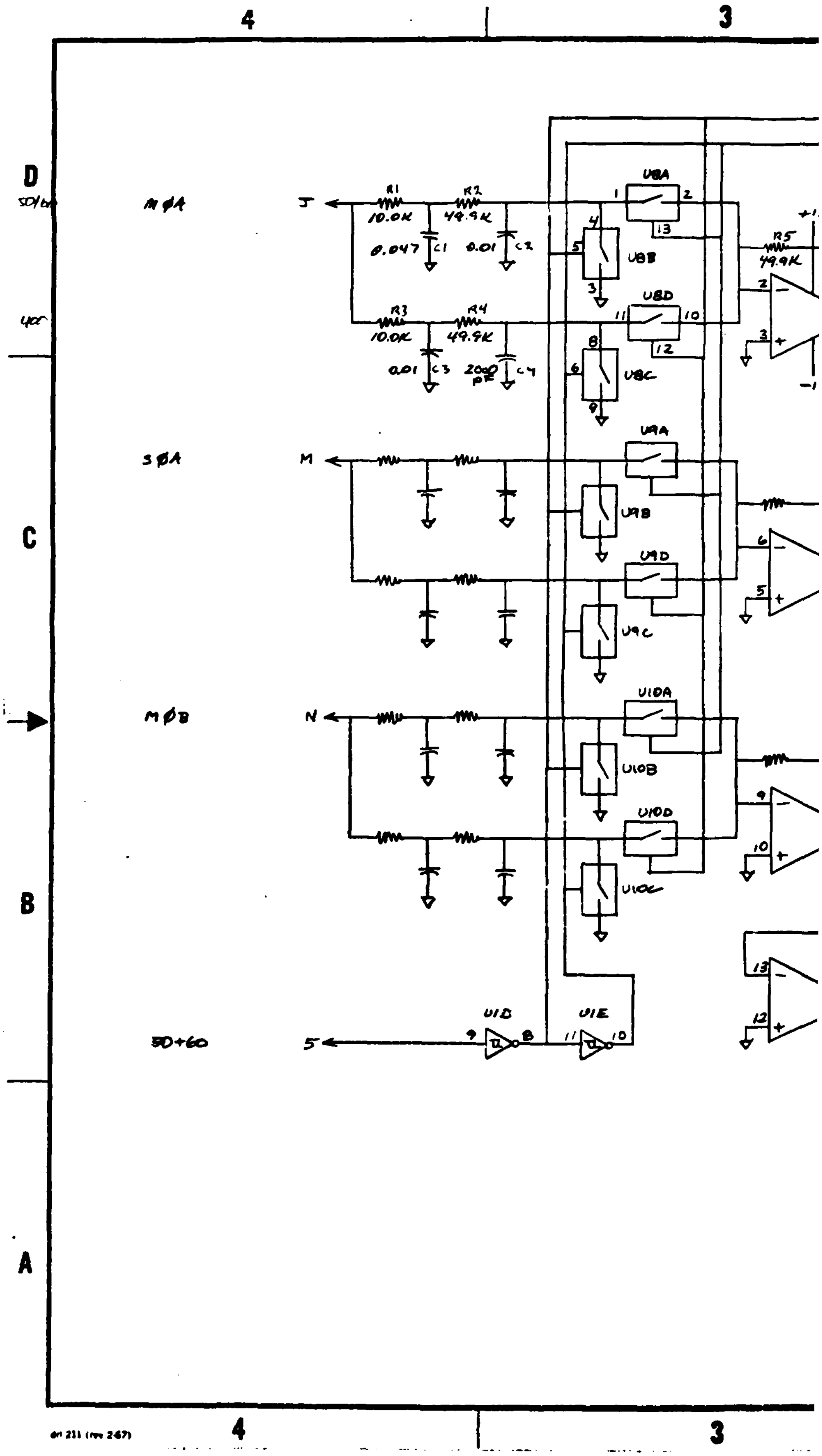
Size	Code Ident No	Dwg No.	Rev
C	13190	SK003912	B

Scale — Sheet 1 of 2

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±
MATERIAL

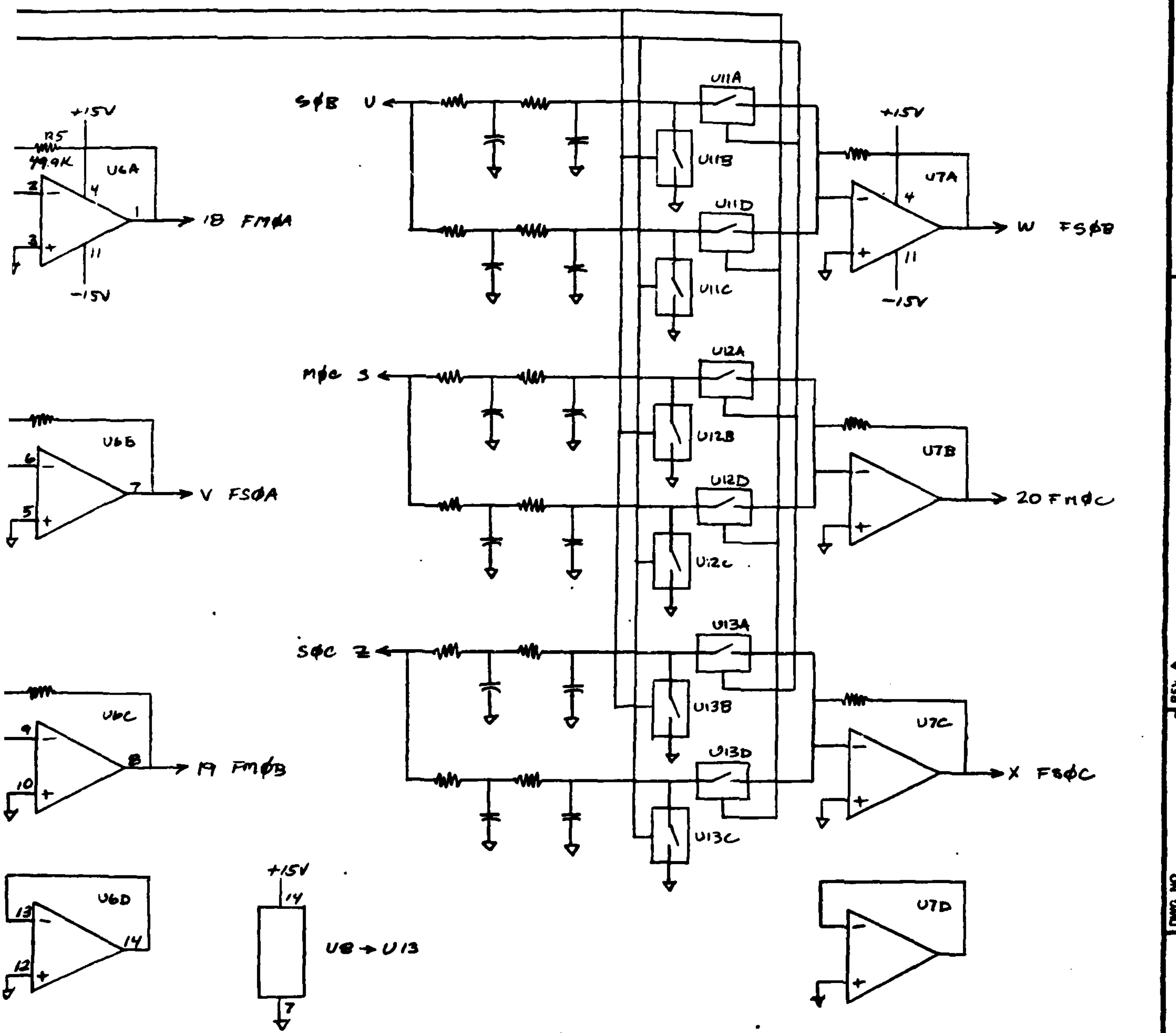
A.H.B. 13 NOV 81
G.H. Booth 13 NOV 81

M-10a



dri 211 (rev 2-67)

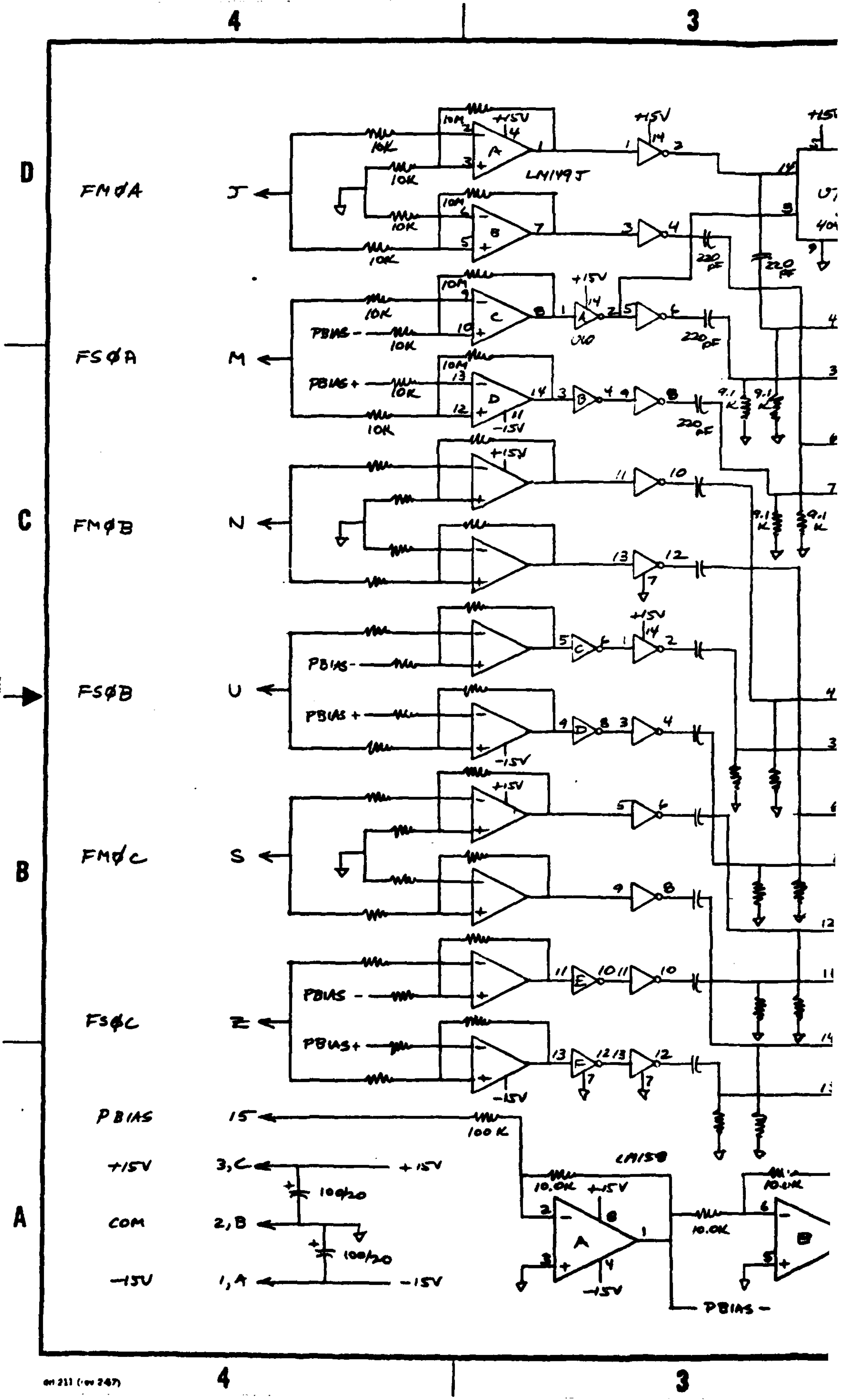
2 1



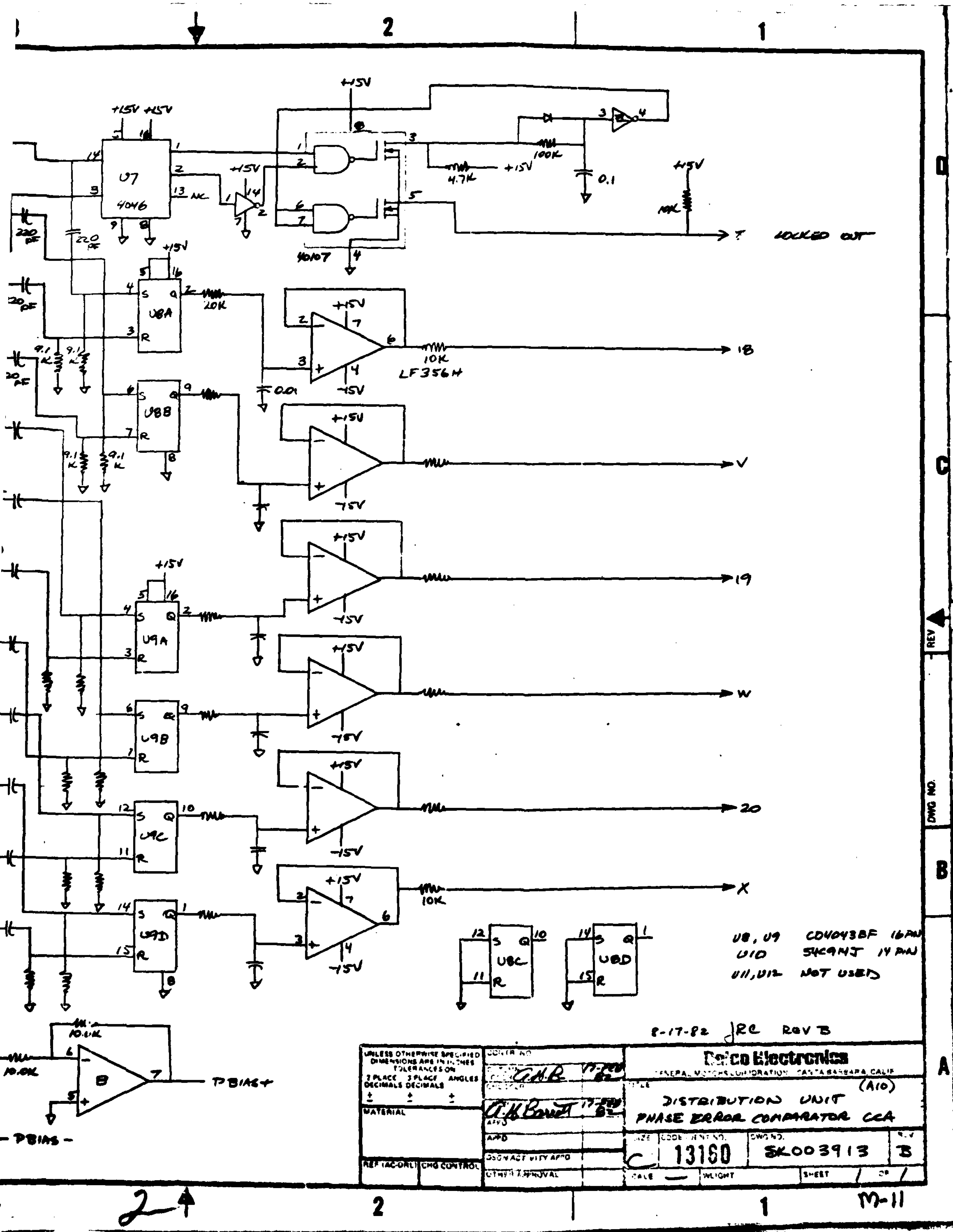
U6, U7 LM148J
U8→U13 CD4066BF
ALL RESISTORS RNC55H

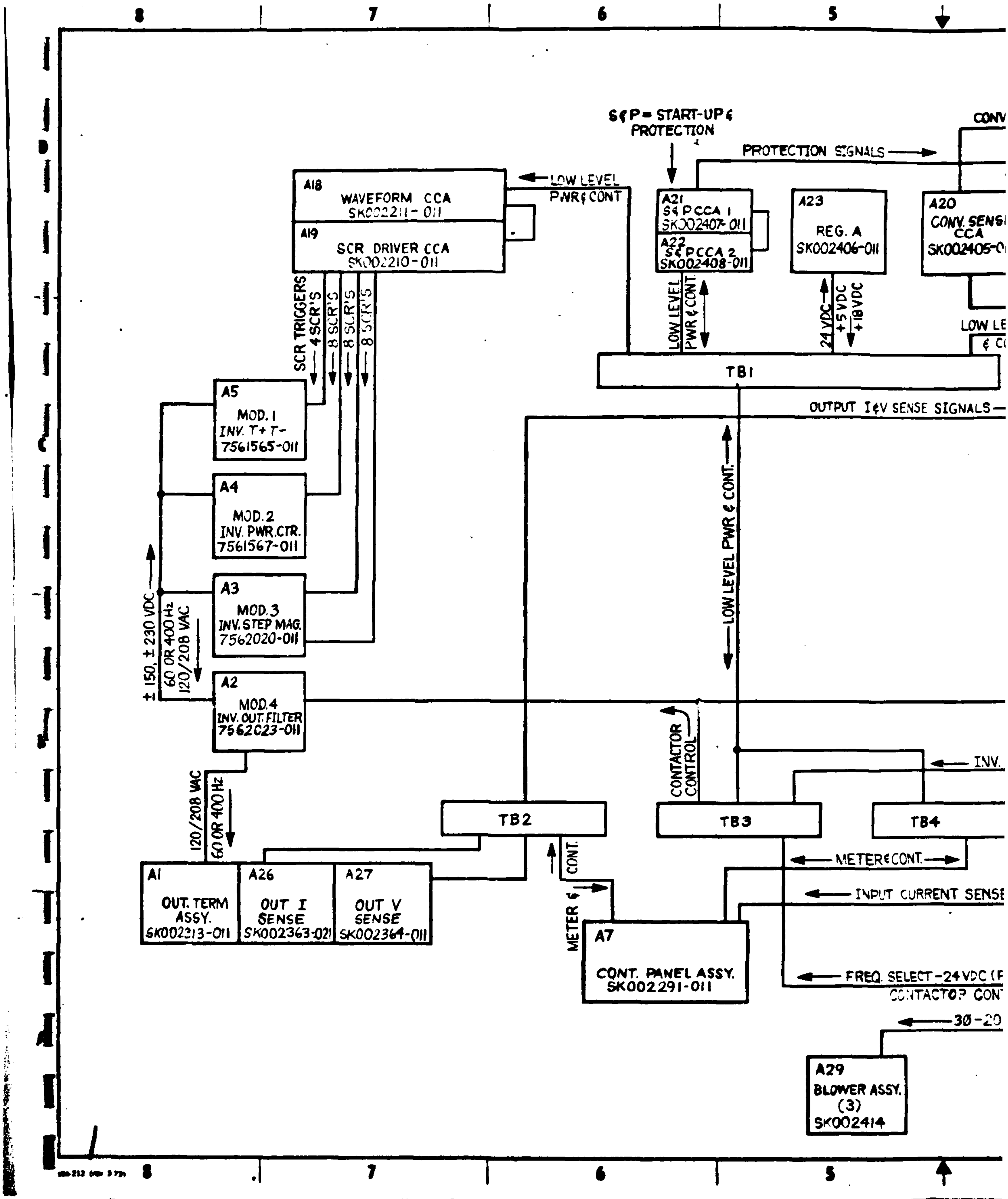
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	G.H.B. 6 DEC 81	Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.
MATERIAL	G.H. Barrett 6 DEC 81	DISTRIBUTION UNIT REM/LOC, REF PHASE, & Ø VOLT FILTERS A6B
	APPD	SIZE C · CODE IDENT NO. 13160 · DWG NO. SK003912 · REV B
REF TAC ORG · CHG CONTROL	OTHER APPROVAL	SCALE · WEIGHT · SHEET 2 OF 2

2 1 M-10B

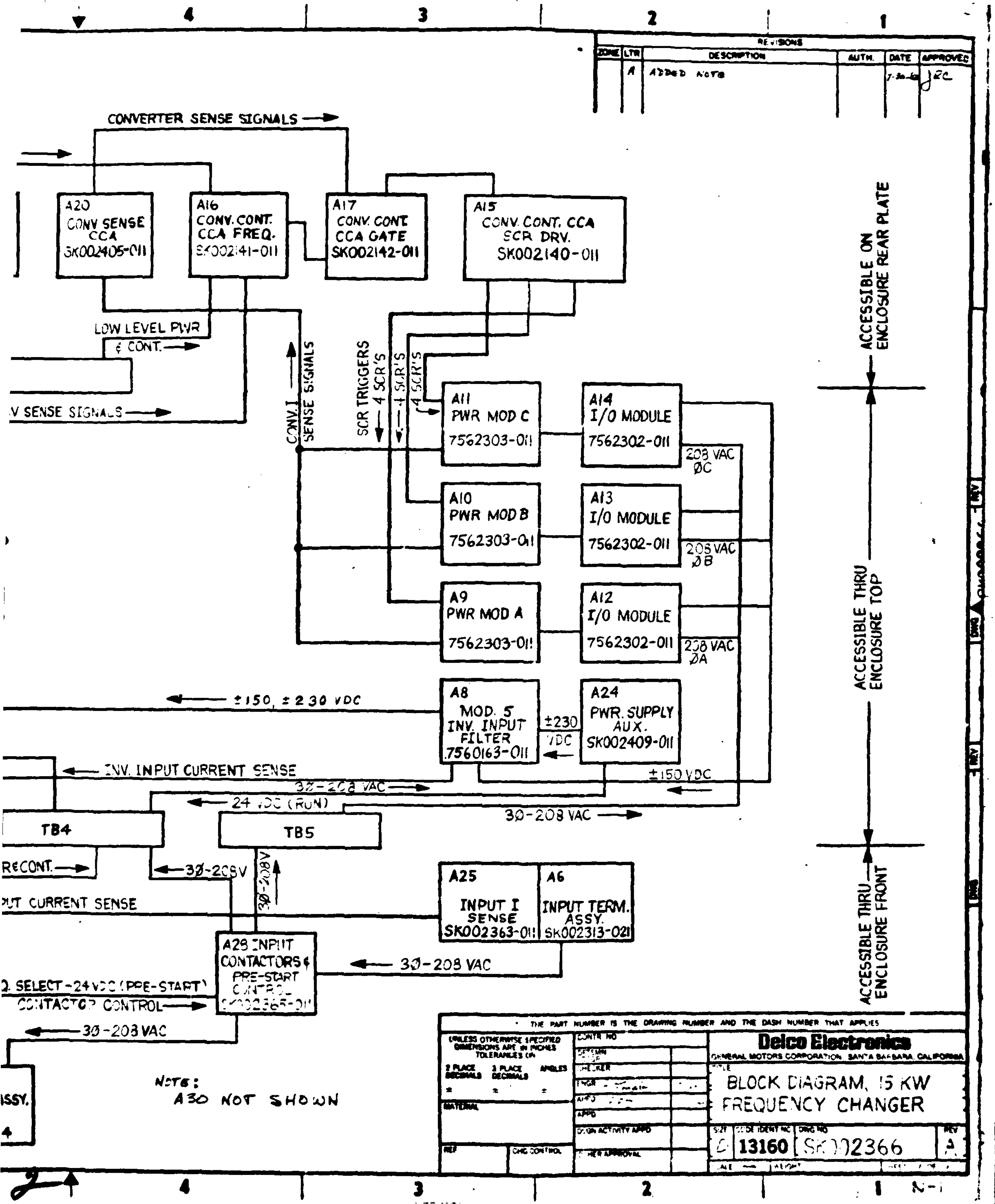


4
3
D
C
B
A
FMØA
J
FSØA
M
FMØB
N
FSØB
U
FMØC
S
FSØC
Z
PBIAS
15
+15V
3,C
COM
2,B
-15V
1,A
LM149J
LM158
PBIAS -
PBIAS +
100 K
10.0K
100/20


U7
4046
+15V
40107
LOCKED OUT
100K
4.7K
0.1
10K
220 pF
U8A
U8B
20K
LF356H
0.01
9.1 K
18
V
19
U9A
U9B
W
U9C
20
U9D
X
U8C
U8D
U8, U9 CD4043BF 16 PIN
U10 54C9MJ 14 PIN
U11, U12 NOT USED
10.0K
PBIAS+
- PBIAS -
8-17-82 JRC REV B
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
2 PLACE DECIMALS 3 PLACE DECIMALS ANGLES
MATERIAL
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
(A10)
DISTRIBUTION UNIT
PHASE ERROR COMPARATOR CCA
C
13160
SK003913
B
SHEET 1 OF 1
REV
DWG NO.
M-11



8
7
6
5
S&P = START-UP & PROTECTION
PROTECTION SIGNALS
CONV
A18
WAVEFORM CCA
SK002211-011
A19
SCR DRIVER CCA
SK002210-011
LOW LEVEL PWR & CONT
A21
S&P CCA 1
SK002407-011
A22
S&P CCA 2
SK002408-011
A23
REG. A
SK002406-011
A20
CONV. SENSE CCA
SCR TRIGGERS
4 SCR'S
8 SCR'S
8 SCR'S
8 SCR'S
LOW LEVEL PWR & CONT.
24 VDC
+5 VDC
+18 VDC
TB1
OUTPUT I&V SENSE SIGNALS
A5
MOD. 1
INV. T+ T-
7561565-011
A4
MOD. 2
INV. PWR. CTR.
7561567-011
A3
MOD. 3
INV. STEP MAG.
7562020-011
A2
MOD. 4
INV. OUT. FILTER
7562023-011
± 150, ± 230 VDC
60 OR 400 Hz
120/208 VAC
LOW LEVEL PWR & CONT.
CONTACTOR CONTROL
INV.
120/208 VAC
60 OR 400 Hz
TB2
TB3
TB4
CONT.
METER &
METER & CONT.
INPUT CURRENT SENSE
A1
OUT. TERM ASSY.
SK002213-011
A26
OUT I SENSE
SK002363-021
A27
OUT V SENSE
SK002364-011
A7
CONT. PANEL ASSY.
SK002291-011
FREQ. SELECT -24 VDC
CONTACTOR CONT
30-20
A29
BLOWER ASSY.
(3)
SK002414


REVISIONS
ZONE LTR DESCRIPTION AUTH. DATE APPROVED
A ADDED NOTE
CONVERTER SENSE SIGNALS
A20 CONV SENSE CCA SK002405-011
A16 CONV. CONT. CCA FREQ. SK002141-011
A17 CONV. CONT. CCA GATE SK002142-011
A15 CONV. CONT. CCA SCR DRV. SK002140-011
LOW LEVEL PWR & CONT.
V SENSE SIGNALS
CONV.1 SENSE SIGNALS
SCR TRIGGERS 4 SCR'S
4 SCR'S
4 SCR'S
A11 PWR MOD C 7562303-011
A14 I/O MODULE 7562302-011
208 VAC ØC
A10 PWR MOD B 7562303-011
A13 I/O MODULE 7562302-011
208 VAC ØB
A9 PWR MOD A 7562303-011
A12 I/O MODULE 7562302-011
208 VAC ØA
±150, ±230 VDC
A8 MOD. 5 INV. INPUT FILTER 7560163-011
±230 VDC
A24 PWR. SUPPLY AUX. SK002409-011
INV. INPUT CURRENT SENSE
±150 VDC
3Ø-208 VAC
24 VDC (RUN)
3Ø-208 VAC
TB4
TB5
RECONT.
3Ø-208V
3Ø-208V
PUT CURRENT SENSE
A25 INPUT I SENSE SK002363-011
A6 INPUT TERM. ASSY. SK002313-021
A28 INPUT CONTACTORS & PRE-START CONTROL SK002365-011
3Ø-208 VAC
SELECT -24 VDC (PRE-START)
CONTACTOR CONTROL
3Ø-208 VAC
ASSY.
ACCESSIBLE ON ENCLOSURE REAR PLATE
ACCESSIBLE THRU ENCLOSURE TOP
ACCESSIBLE THRU ENCLOSURE FRONT
NOTE: A30 NOT SHOWN
THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
2 PLACE DECIMALS 3 PLACE DECIMALS ANGLES
MATERIAL
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA
BLOCK DIAGRAM, 15 KW FREQUENCY CHANGER
13160
SK002366
A
4 3 2 1
N-1

- 15 kW POWER CONDITIONER (FREQUENCY CHANGER) SK002447-011
  - WIRE/INTERCONNECT DIAGRAM SK002459
  - BLOCK DIAGRAM SK002366
  - SUPPORT FUNCTIONS — SCHEMATIC SK002427
    - ENCLOSURE ASSEMBLY SK002309-011
    - A7 CONTROL PANEL ASSY SK002291-011
    - A1 OUTPUT TERMINAL ASSY SK002313-011
    - A6 INPUT TERMINAL ASSY SK002313-021
    - A20 CONVERTER SENSE CCA SK002405-011
    - A23 REGULATOR A SK002406-011
    - A21 S&P CCA, NO. 1 SK002407-011
    - A22 S&P CCA, NO. 2 SK002408-011
    - A24 POWER SUPPLY AUXILIARY SK002409-011
    - A25 INPUT I SENSE SK002363-011
    - A26 OUTPUT I SENSE SK002363-021
    - A27 OUTPUT V SENSE SK002364-011
    - A28 INPUT, CONTACTORS AND PRE-START CONTROL SK002365-011
    - A29 BLOWER ASSEMBLY SK002414
      - BLOWER (3 REQD) 760120 VZ 282
      - PLATE SK002309-028
    - A30 PARALLELING CONTROL SK002746
  - INVERTER GROUP — SCHEMATIC SK002136
    - A5 MODULE 1, INVERTER, T+ T- 7561565-011
    - A4 MODULE 2, INVERTER, POWER CENTERS 7561567-011
    - A3 MODULE 3, INVERTER, STEPS/MAGNETICS 7562020-011
    - A2 MODULE 4, INVERTER, OUTPUT FILTER 7562023-011
    - A8 MODULE 5, INVERTER, INPUT FILTER 7560163-011
    - A19 SCR DRIVER, CCA SK002210-011
      - PWB, SCR DRIVER 7557952-011
    - A18 WAVE FORM, CCA SK002211-011
      - PWB, WAVE FORM 7557950-011

MIL 1000C

3 2 1

REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPD
	A	CHANGED TITLE, ADDED A30	9-30-82	JRC

D

IC
5

ERTER,

ERTER,

ERTER,

ERTER,

ERTER,

CCA

ER

CCA

CONVERTER GROUP — SCHEMATIC SK002135

- A9, A10, A11 POWER MODULE 7562303-011 (3 REQD)
- A12, A13, A14 I/O MODULE 7562302-011 (3 REQD)
- A15 CONVERTER CONTROL CCA, SCR DRIVER SK002140-011
  - PWB, CONVERTER CONTROL, SCR DRIVER 7558461-011
- A16 CONVERTER CONTROL CCA, FREQUENCY SK002141-011
  - PWB, CONVERTER CONTROL, FREQUENCY 7558459-011
- A17 CONVERTER CONTROL CCA, GATE SK002142-011
  - PWB, CONVERTER CONT. 7558460-011

C

SK002367

B

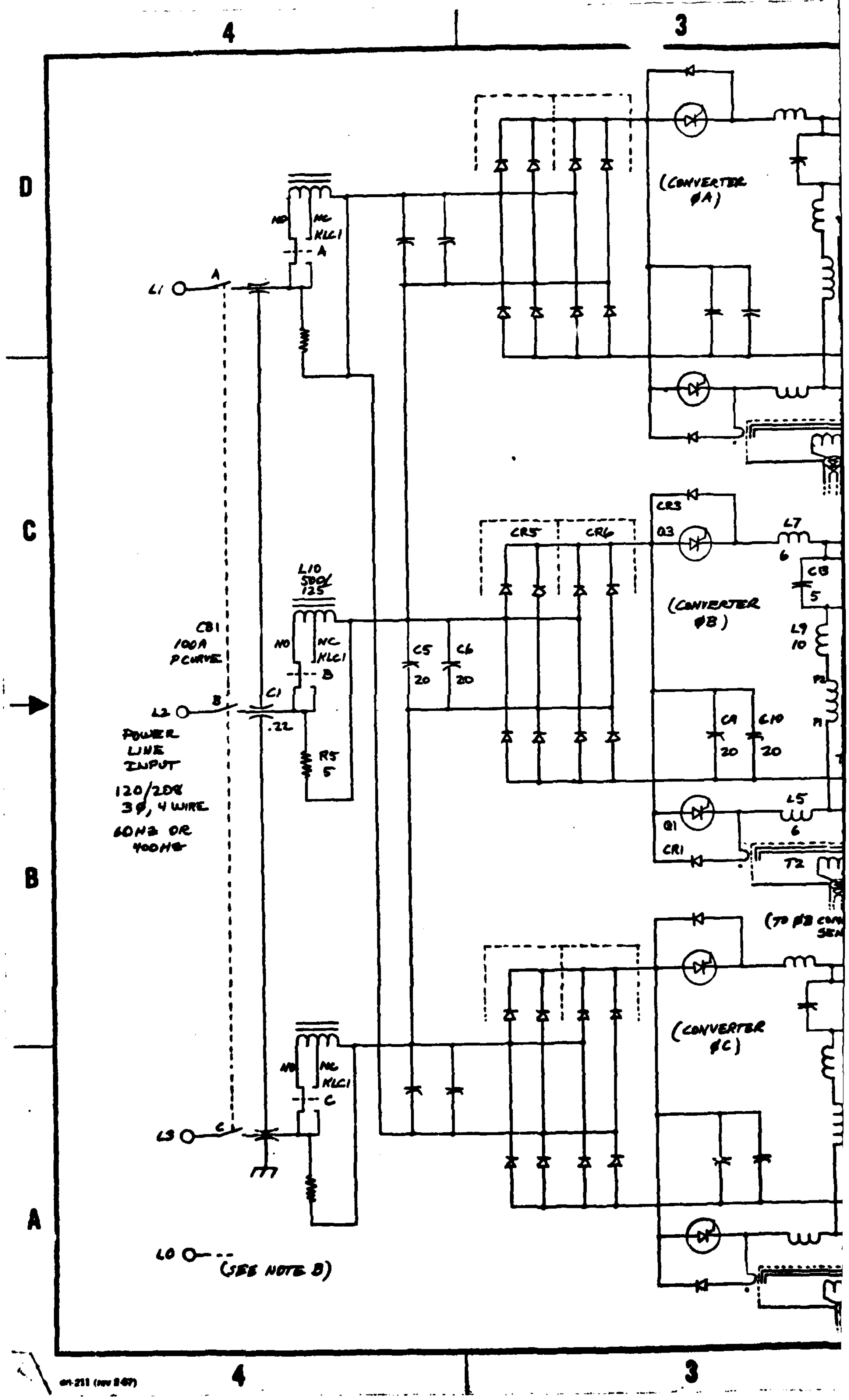
-001 DASH NO.

THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

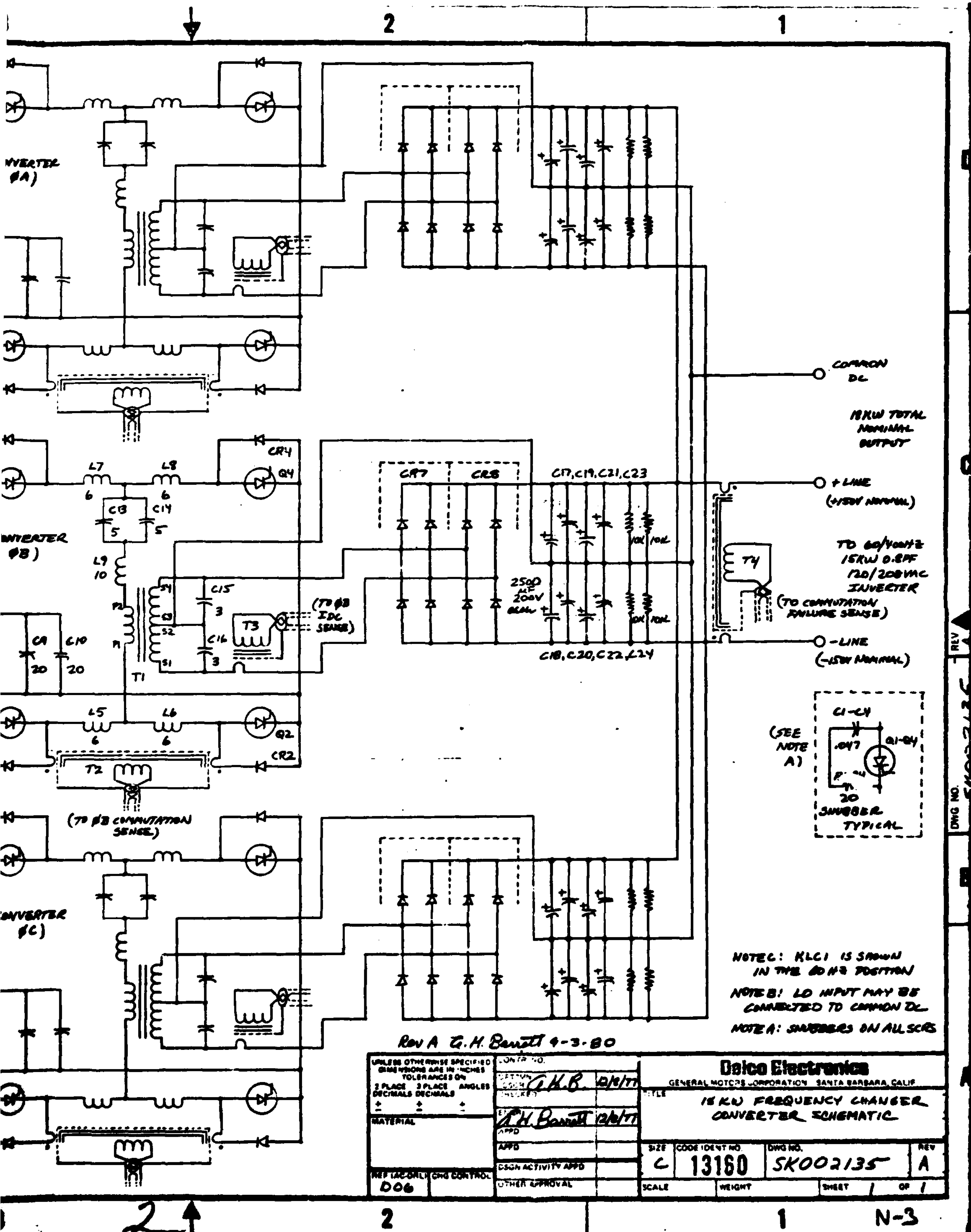
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON: 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR. NO.	**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA
	DFTSMN/DSGR W.T. 5/11/79	TITLE FAMILY TREE, 15KW FREQUENCY CHANGER
	CHECKER	
	ENGR R TEMPLE 6/22/79	
MATERIAL	APPD	
	APPD	
	DSGN ACTIVITY APPD	SIZE C — CODE IDENT NO 13160 — DWG NO. SK002367 — REV A
REF 006 — CHG CONTROL	OTHER APPROVAL	SCALE NONE — WEIGHT — SHEET 1 OF 1

A

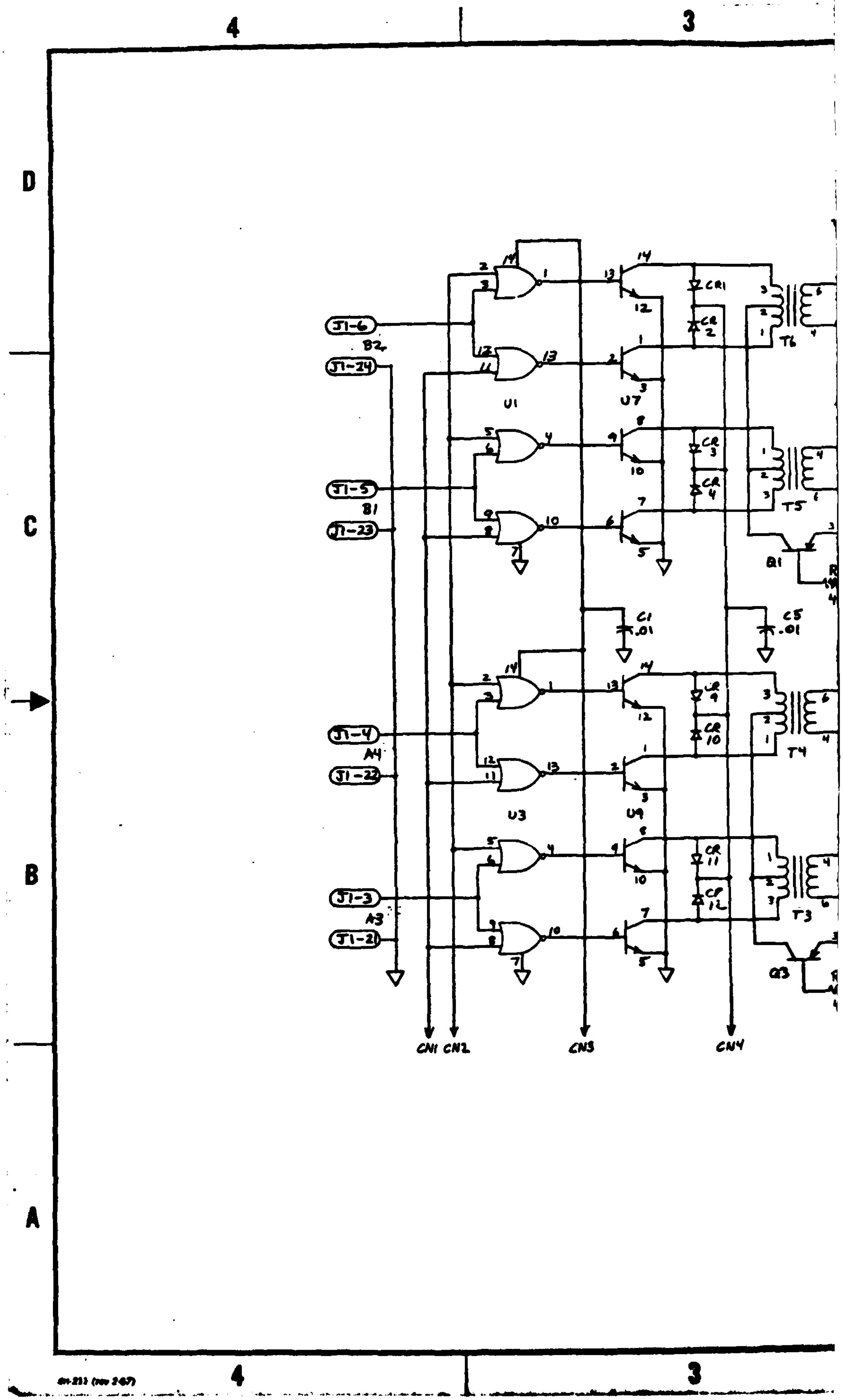
2A 2 1



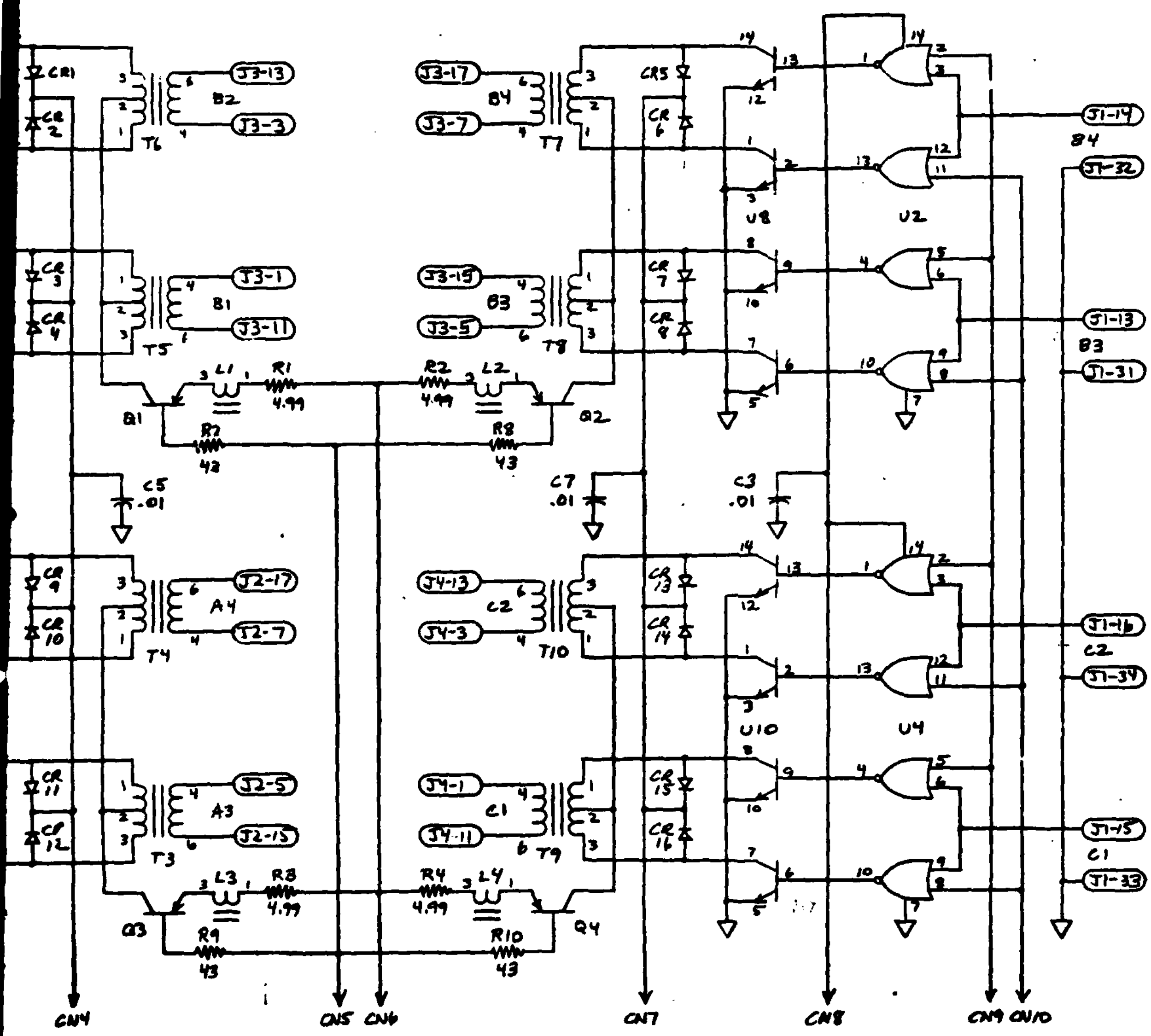
4
3
D
C
B
A
(CONVERTER ØA)
(CONVERTER ØB)
(CONVERTER ØC)
L1
L2
L3
L0
(SEE NOTE B)
NO
NC
KLC1
CB1
100A
P CURVE
C1
.22
R5
5
L10
500/
125
C5
20
C6
20
CR5
CR6
CR3
Q3
L7
6
C8
5
L9
10
C9
20
C10
20
L5
6
Q1
CR1
T2
POWER
LINE
INPUT
120/208
3Ø, 4 WIRE
60HZ OR
400HZ



2
1
INVERTER (ØA)
CR4
Q4
L7 6
L8 6
C13 5
C14 5
INVERTER (ØB)
L9 10
T1
C15 3
C16 3
C9 20
C10 20
T3
(TO ØB IDC SENSE)
CR7
CR8
C17, C19, C21, C23
2500 µF 200V
10K
C18, C20, C22, C24
L5 6
L6 6
Q2
CR2
T2
(TO ØB COMMUTATION SENSE)
INVERTER (ØC)
COMMON DC
15KW TOTAL NOMINAL OUTPUT
+LINE (+15V NOMINAL)
T4
TO 60/400HZ 15KW 0.8PF 120/208VAC INVERTER
(TO COMMUTATION FAILURE SENSE)
-LINE (-15V NOMINAL)
(SEE NOTE A)
C1-C4
.047
Q1-Q4
20
SNUBBER TYPICAL
NOTE C: KLC1 IS SHOWN IN THE 60HZ POSITION
NOTE B: LO INPUT MAY BE CONNECTED TO COMMON DC
NOTE A: SNUBBERS ON ALL SCRS
Rev A G.H. Barrett 4-3-80
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
2 PLACE DECIMALS ±
3 PLACE DECIMALS ±
ANGLES ±
MATERIAL
NEXT ASSY
USED ON
DOG
CONTR NO.
DRAWN G.K.B. 12/6/77
CHECKED
ENGR G.H. Barrett 12/6/77
APPD
APPD
DSGN ACTIVITY APPD
OTHER APPROVAL
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.
TITLE 15 KW FREQUENCY CHANGER CONVERTER SCHEMATIC
SIZE C
CODE IDENT NO. 13160
DWG NO. SK002135
REV A
SCALE
WEIGHT
SHEET 1 OF 1
2
1
N-3

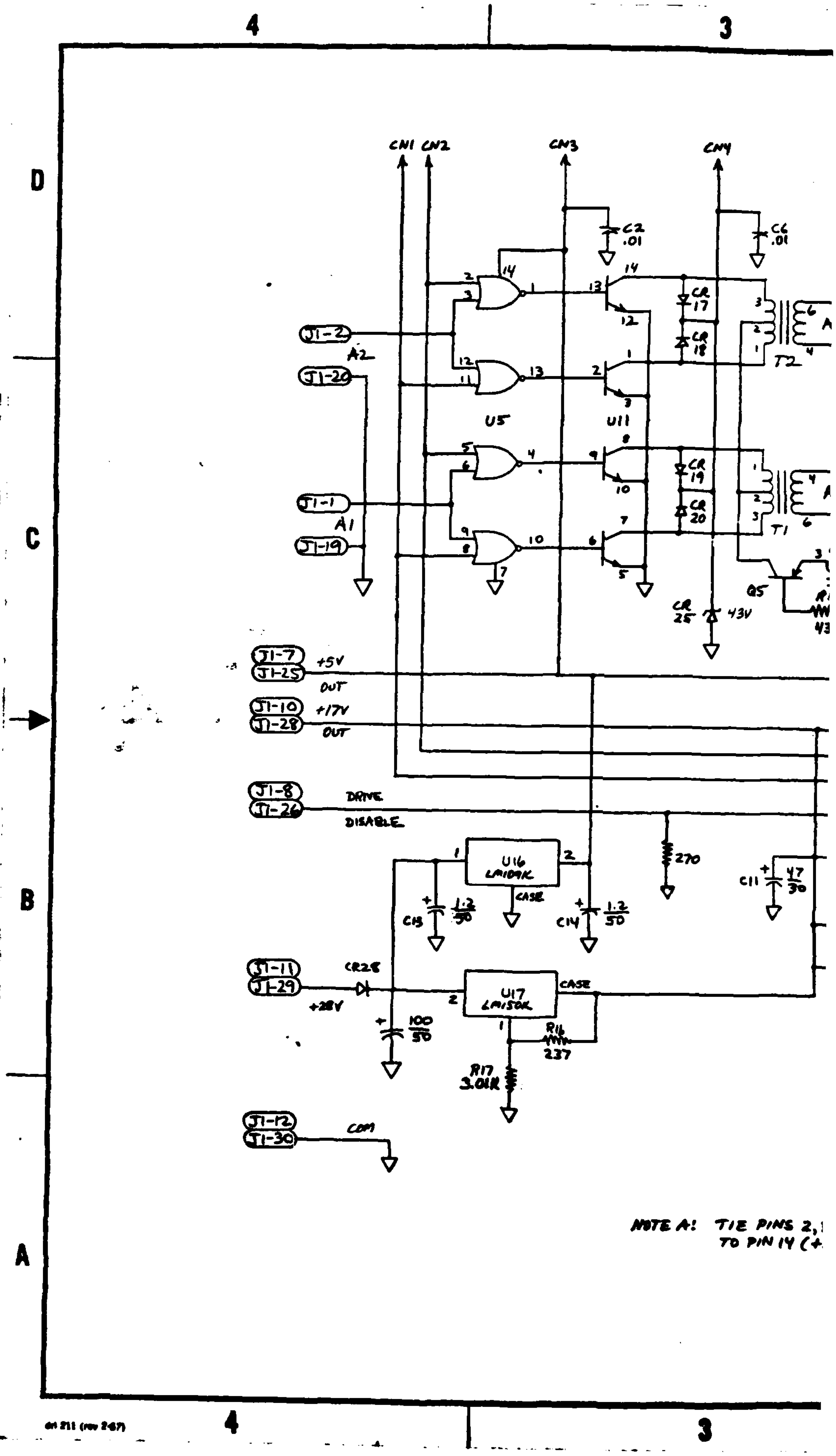


4
3
D
C
B
A
J1-6
B2
J1-24
J1-5
B1
J1-23
J1-4
A4
J1-22
J1-3
A3
J1-21
U1
U7
U3
U9
CR1
CR 2
CR 3
CR 4
CR 9
CR 10
CR 11
CR 12
T6
T5
T4
T3
Q1
Q3
C1 .01
C5 .01
CN1 CN2
CN3
CN4

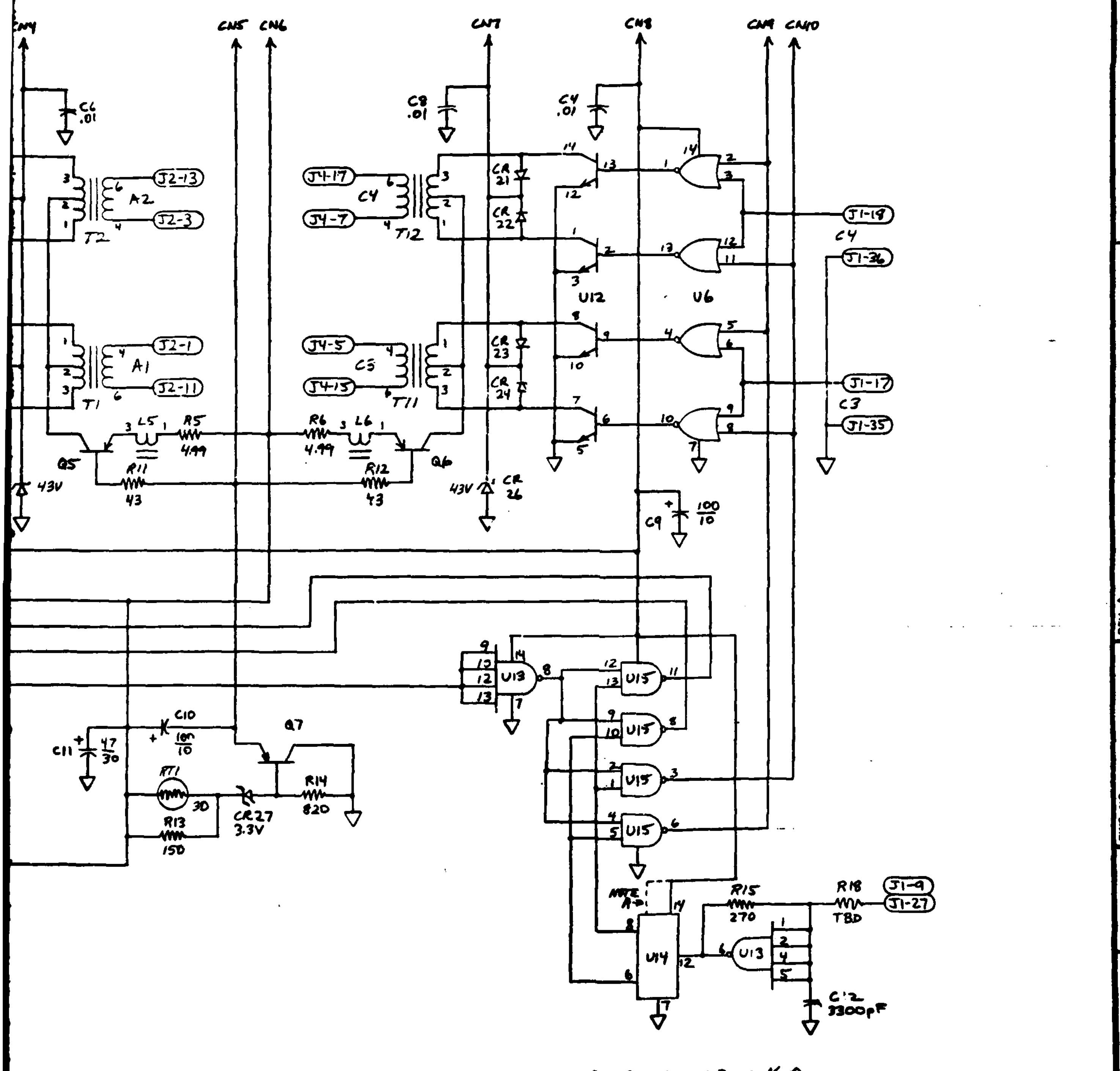


REV B 9-3-80 G.K.B.
REV. A 10/23/78 G.K.B.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO.		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.
	DRAWN	G.K.B. 3/15/78	
	CHECKED		TITLE 15KW FREQUENCY CHANGER CONVERTER GATE DRIVERS
MATERIAL	ENGR	A.H. Barrett 3/15/78	
	APPD		
	APPD		SIZE C · CODE IDENT NO. 13160 · DWG NO. SK002140 · REV B
REF (AC-DRL) · CHG CONTROL	DSGN ACTIVITY APPD		
	OTHER APPROVAL		SCALE · WEIGHT · SHEET 2 OF



CN1 CN2 CN3 CN4
C2 .01
C6 .01
U5
U11
CR 17
CR 18
CR 19
CR 20
T2
T1
Q5
CR 25 43V
J1-2
A2
J1-20
J1-1
A1
J1-19
J1-7 +5V
J1-25 OUT
J1-10 +17V
J1-28 OUT
J1-8 DRIVE
J1-26 DISABLE
270
C11 47/30
U16 LM109K
CASE
C13 1.2/50
C14 1.2/50
J1-11
J1-29
CR28
+28V
U17 LM150K
CASE
100/50
R16 237
R17 3.01K
J1-12
J1-30
COM
NOTE A: TIE PINS 2,
TO PIN 14 (+



TIE PINS 2,3,4,5,9,10,11 AND 13 TO PIN 14 (+5V)

REV B 9-3-80 C.K.B.
REV. A 10/23/79 C.K.B.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO / DFTSMN C.K.B. 3/15/78 / CHECKER C.K. Barrett 3/15/78	Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA
MATERIAL	APPD / APPD / GOVN ACTIVITY APPD / OTHER APPROVAL	TITLE 15KW FREQUENCY CHANGER CONVERTER GATE DRIVERS
REF (AC ONLY) / CHG CONTROL		SIZE C / CODE IDENT NO 13160 / DWG NO SK002140 / SCALE / WEIGHT

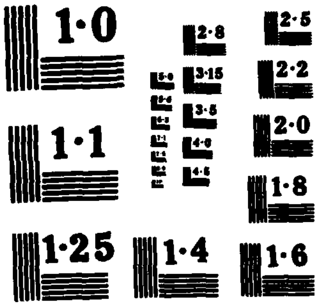
3 2 1

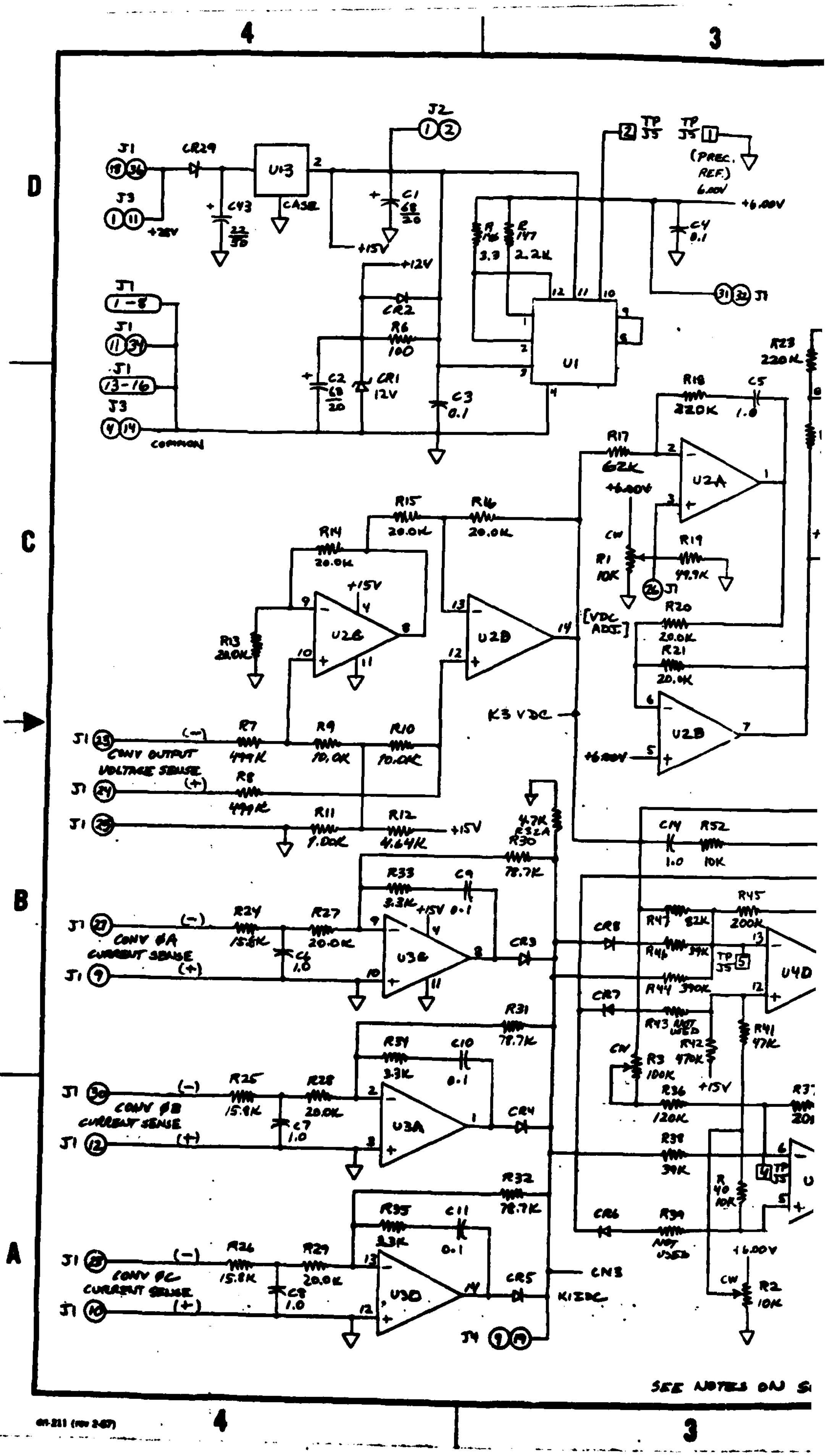
N-48

AD A145 531 PROGRESS IN POWER DISTRIBUTION IN FISCAL YEAR 1982(U) 4/4
GENERAL MOTORS CORP GOLETA CA DELCO ELECTRONICS DIV
OCT 82 R82-127

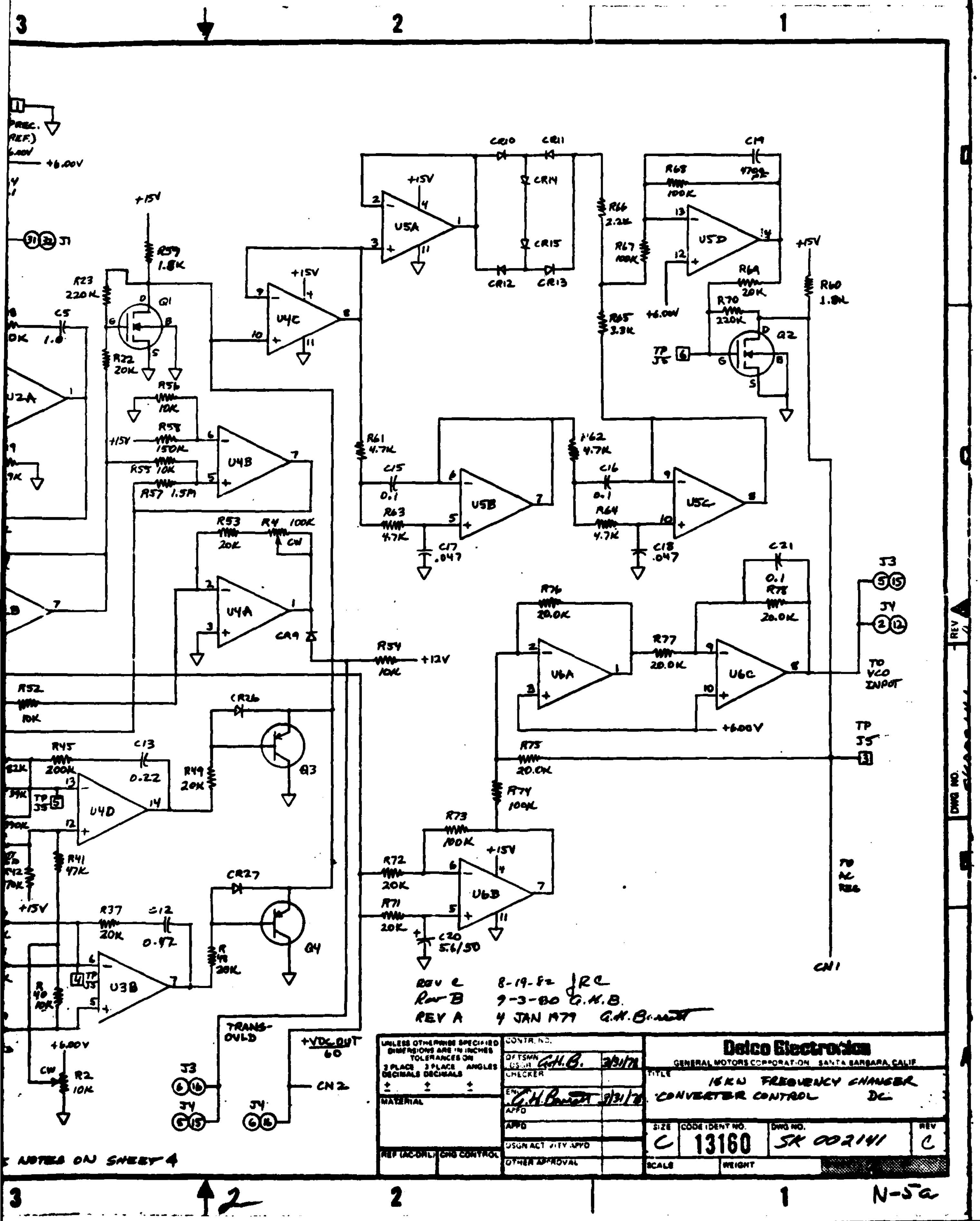
UNCLASSIFIED F/G 10/2 NL

END
DATE
FILMED
10 84

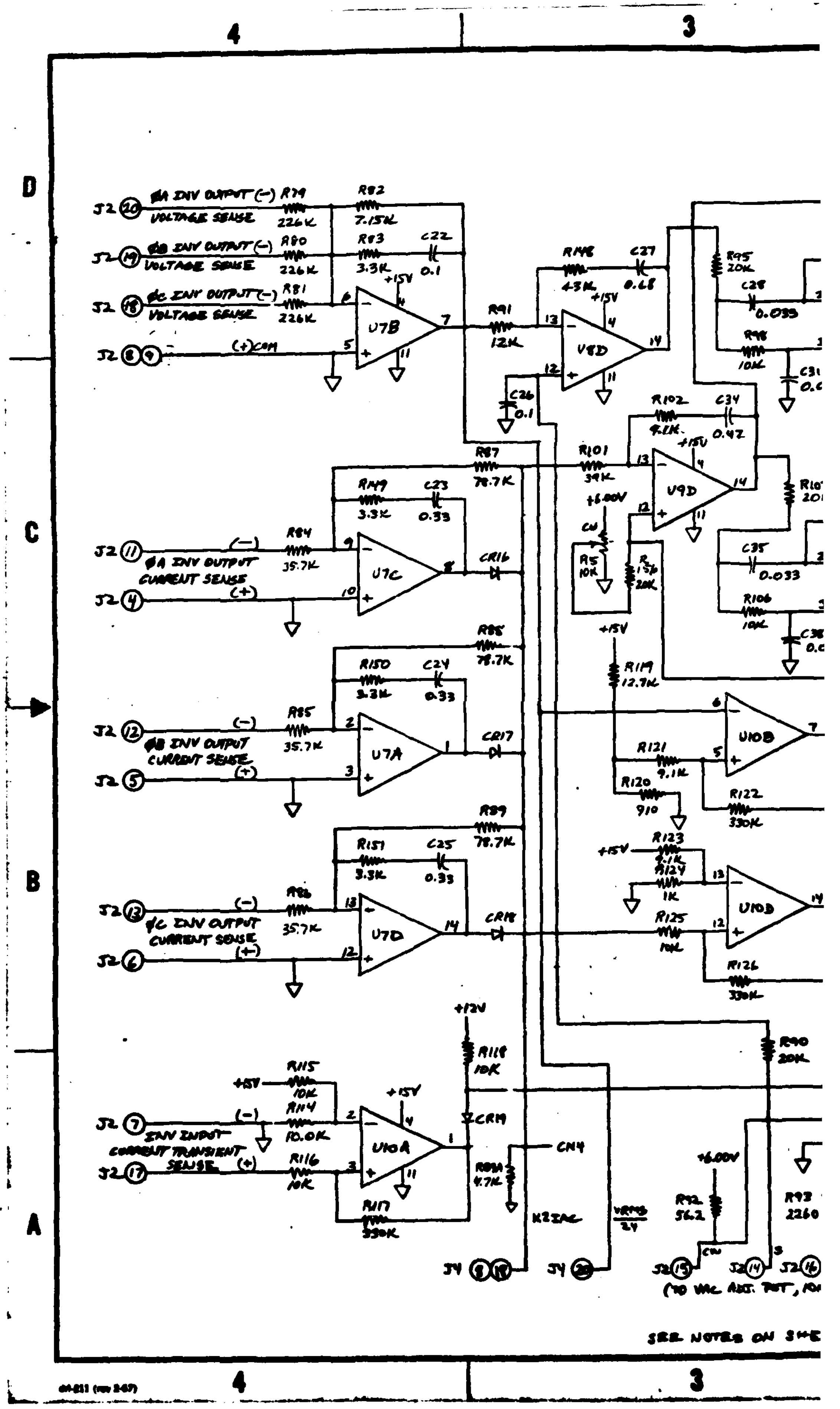

1·0
2·8
2·5
3·15
2·2
3·5
1·1
4·0
2·0
4·5
1·8
1·25
1·4
1·6



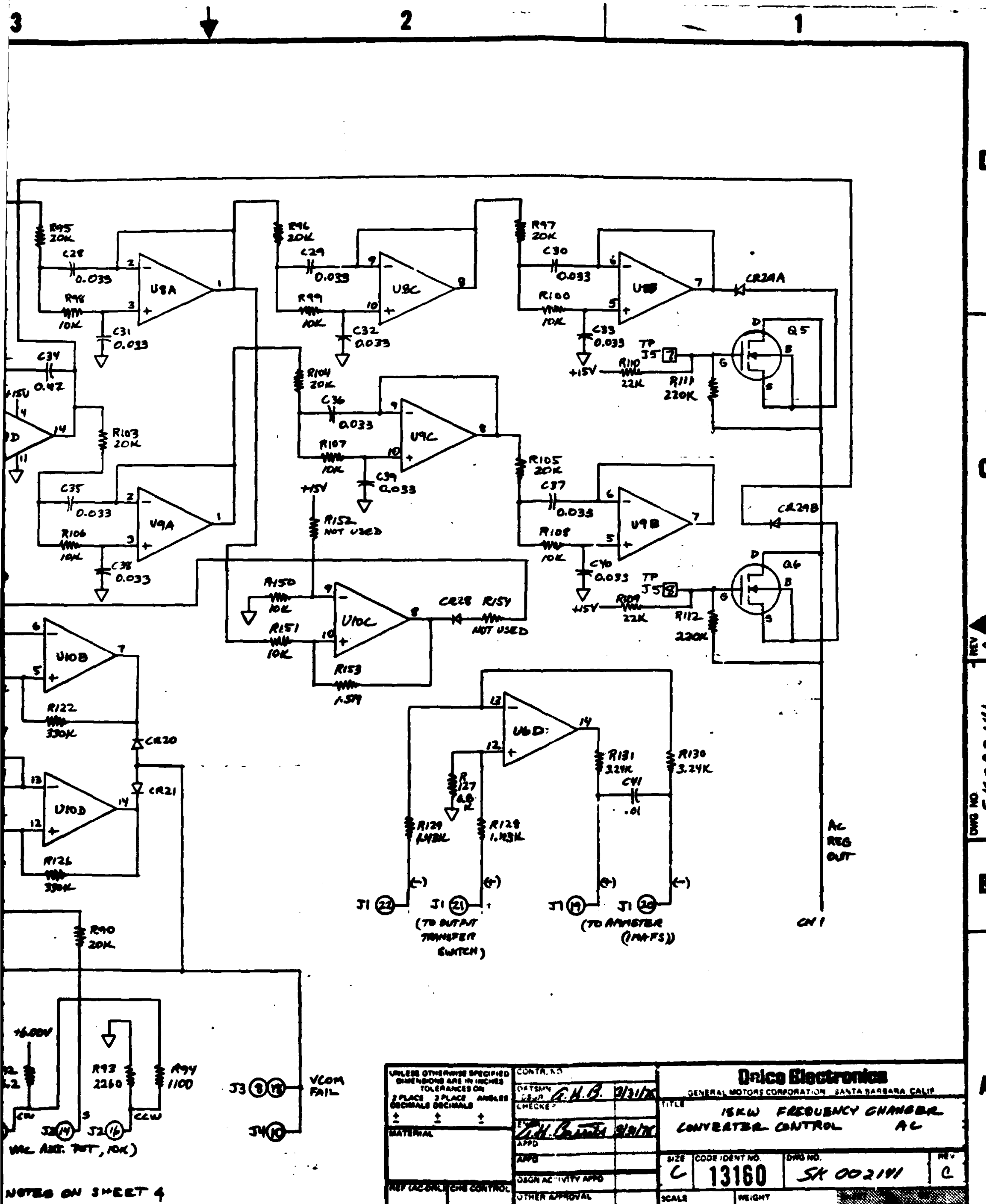
GR-211 (rev 2-87)



3
2
1
+6.00V
+15V
R59 1.8K
Q1
R23 220K
R22 20K
C5 1.0
U2A
R56 10K
R58 150K
R55 10K
R57 1.5M
U4B
U4C
U5A
CR10
CR11
CR14
CR15
CR12
CR13
C19 470pF
R68 100K
R66 2.2K
R67 100K
U5D
R69 20K
R70 220K
R60 1.8K
R65 3.3K
Q2
TP J5 6
R61 4.7K
C15 0.1
R63 4.7K
C17 .047
U5B
R62 4.7K
C16 0.1
R64 4.7K
C18 .047
U5C
R53 20K
R4 100K
CW
U4A
CR9
R54 10K
+12V
R52 10K
CR26
Q3
R45 200K
C13 0.22
R49 20K
U4D
R41 47K
CR27
Q4
R37 20K
C12 0.47
R48 20K
U3B
R40 10K
R2 10K
C21 0.1
R78 20.0K
R76 20.0K
R77 20.0K
U6A
U6C
J3 5 15
J4 2 12
TO VCO INPUT
TP J5 3
R75 20.0K
R74 100K
R73 100K
R72 20K
R71 20K
C20 5.6/50
U6B
TO AC REG
CN1
TRANS-OVLD
+VDC OUT 60
CN2
J3 6 16
J4 6 15
J4 6 16
NOTES ON SHEET 4
REV C 8-19-82 JRC
Rev B 9-3-80 G.H.B.
REV A 4 JAN 1979 G.H. Bennett
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS 3 PLACE DECIMALS ANGLES
MATERIAL
CONTR. NO.
DFTSMN G.H.B. 3/31/78
CHECKER
ENGR G.H. Bennett 3/31/78
APPD
USGN ACTIVITY APPD
OTHER APPROVAL
REF (AC-ONLY)
ENG CONTROL
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
TITLE 15KW FREQUENCY CHANGER CONVERTER CONTROL DC
SIZE C
CODE IDENT NO. 13160
DWG NO. SK 002141
REV C
SCALE
WEIGHT
N-5a



4
3
D
C
B
A
J2 (20) ΦA INV OUTPUT (−) VOLTAGE SENSE
J2 (19) ΦB INV OUTPUT (−) VOLTAGE SENSE
J2 (18) ΦC INV OUTPUT (−) VOLTAGE SENSE
J2 (8)(9) (+) COM
R79 226K
R80 226K
R81 226K
R82 7.15K
R83 3.3K
C22 0.1
U7B
R91 12K
R148 43K
C27 0.68
U8D
C26 0.1
R95 20K
C28 0.033
R98 10K
C31
R102 9.1K
C34 0.47
R101 39K
U9D
+6.00V
R5 10K
R87 78.7K
R149 3.3K
C23 0.33
J2 (11) ΦA INV OUTPUT CURRENT SENSE
J2 (4)
R84 35.7K
U7C
CR16
C35 0.033
R106 10K
C38
R88 78.7K
R150 3.3K
C24 0.33
J2 (12) ΦB INV OUTPUT CURRENT SENSE
J2 (5)
R85 35.7K
U7A
CR17
R119 12.7K
U10B
R121 9.1K
R120 910
R122 330K
R89 78.7K
R151 3.3K
C25 0.33
J2 (13) ΦC INV OUTPUT CURRENT SENSE
J2 (6)
R86 35.7K
U7D
CR18
R123 9.1K
R124 1K
R125 10K
U10D
R126 330K
+12V
R118 10K
R115 10K
R114 10.0K
R116 10K
J2 (7) INV INPUT CURRENT TRANSIENT SENSE
J2 (17)
U10A
R117 330K
CR19
CN4
R91A 4.7K
K2IAC
VRMS 24
R90 20K
+6.00V
R92 56.2
R93 2260
J4 (8)(18)
J4 (20)
J2 (15)
J2 (14)
J2 (16)
(TO VAC ADJ. POT, 10
SEE NOTES ON SHE



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
2 PLACE DECIMALS ±
3 PLACE DECIMALS ±
ANGLES ±

MATERIAL

REF (ACDRL) | CHG CONTROL

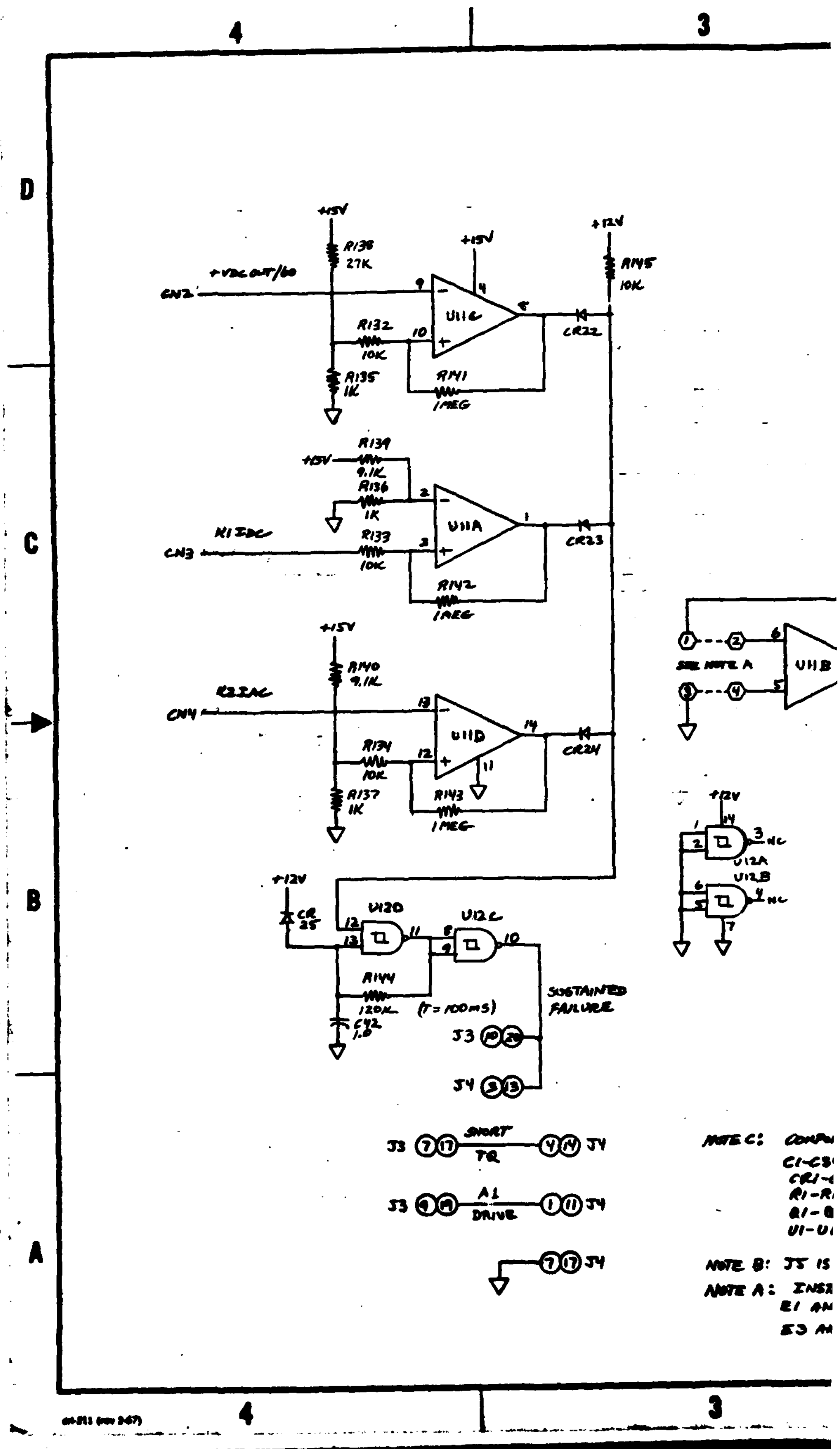
CONTR NO.
DFTSMN G.H.B. 3/31/76
CHECKED
ENGR T.H. Bassett 3/31/76
APPD
APPD
DSGN ACTIVITY APPD
OTHER APPROVAL

Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF

TITLE 15KW FREQUENCY CHANGER CONVERTER CONTROL AC

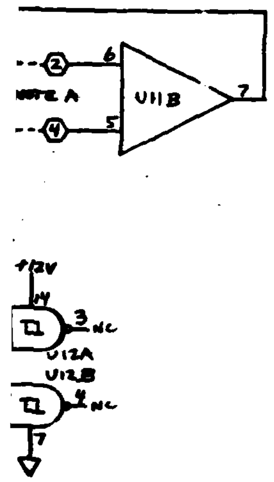
SIZE C | CODE IDENT NO. 13160 | DWG NO. SK 002141 | REV C

SCALE | WEIGHT



+15V
R138
27K
+VDCOUT/60
CN2
+15V
U11C
R145
10K
+12V
CR22
R132
10K
R135
1K
R141
1MEG
R139
9.1K
R136
1K
U11A
CR23
K1IDC
CN3
R133
10K
R142
1MEG
R140
9.1K
R2IAC
CN4
U11D
CR24
R134
10K
R137
1K
R143
1MEG
SEE NOTE A
U11B
U12A
U12B
U12D
U12C
CR25
R144
120K
(T=100mS)
C42
1.0
SUSTAINED
FAILURE
J3
J4
SHORT
TR
A1
DRIVE
NOTE C:
NOTE B:
NOTE A:

2 1



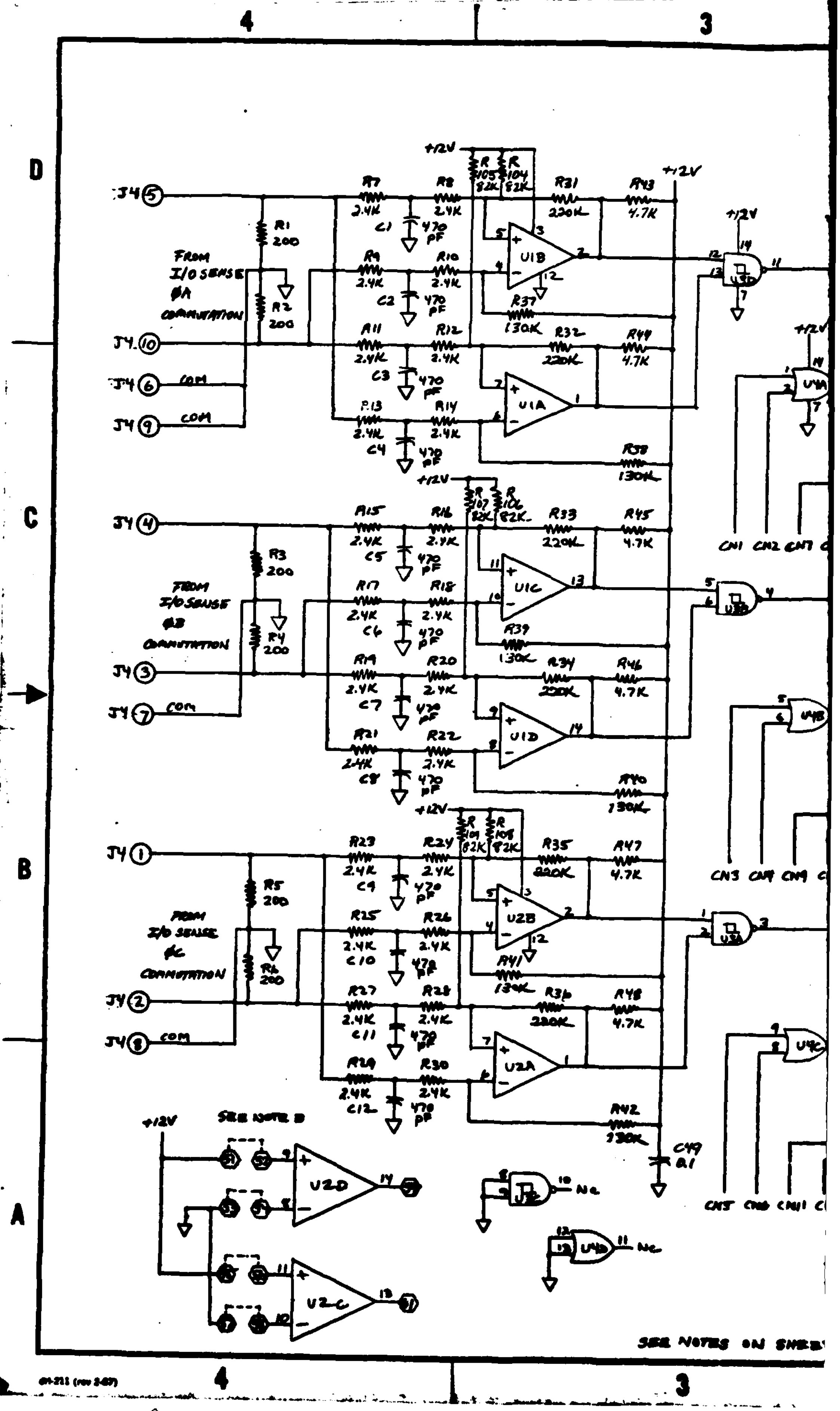
NOTE C: COMPONENT DESIGNATIONS ARE:
C1-C34
CR1-CR29
R1-R156 (except R113, R155)
Q1-Q7
U1-U13

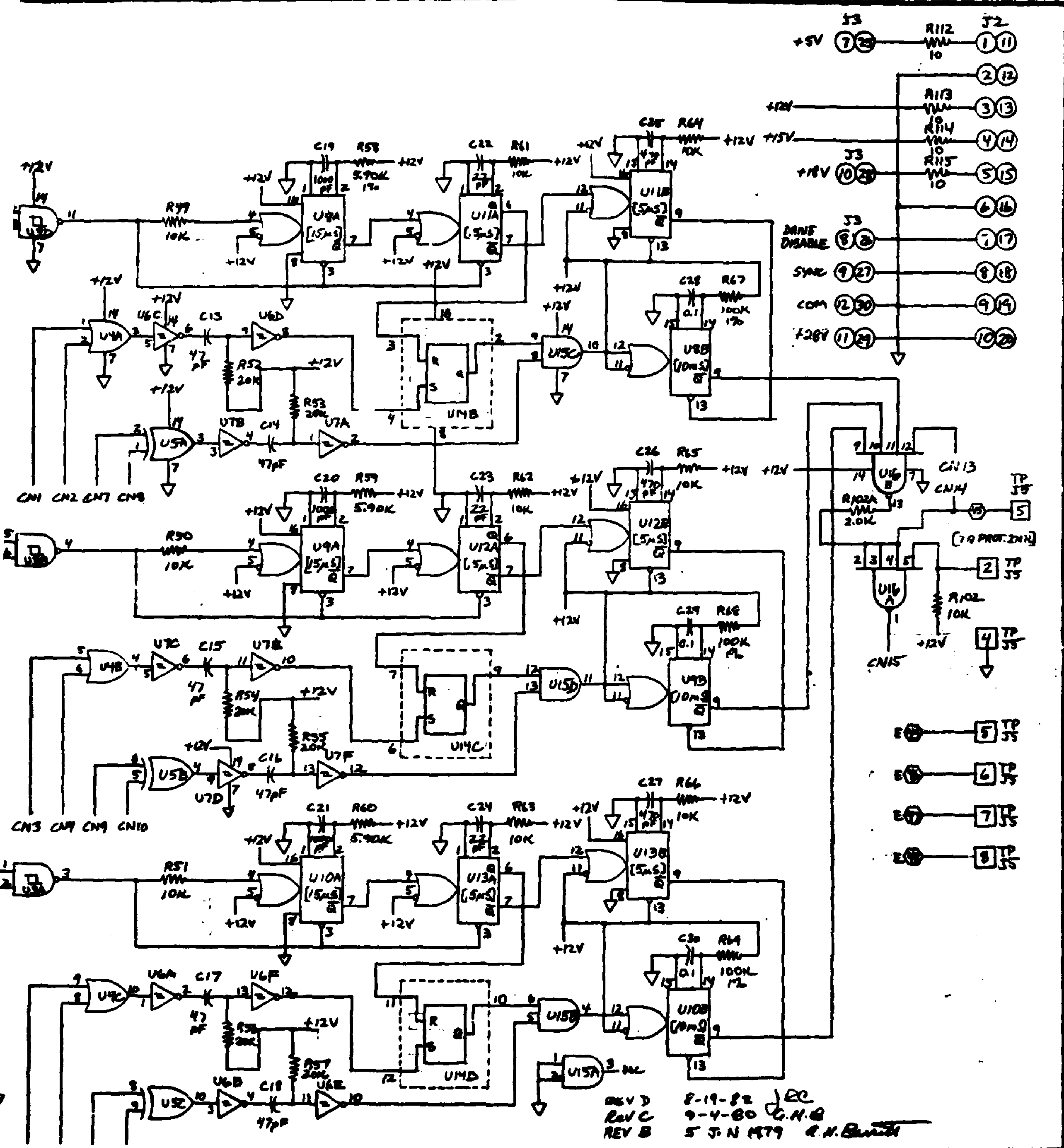
NOTE B: J5 IS A TEST POINT CONNECTOR

NOTE A: INSTALL JUMPERS BETWEEN E1 AND E2 AND BETWEEN E3 AND E4

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR. NO.		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	DFTSMN G.H.B.	3/31/78	
	CHECKER		TITLE 15KW FREQUENCY CHANGER CONVERTER CONTROL AC
MATERIAL	ENGR G.H. Bond	3/31/78	
	APPD		
	APPD		SIZE C · CODE IDENT NO. 13160 · DWG NO. SK 002141 · REV C
NEXT ASSY · DWG CONTROL	DSGN ACTIVITY APPD		
	OTHER APPROVAL		SCALE · WEIGHT

2 1 N-5C


4
3
D
C
B
A
J4 (5)
J4 (10)
J4 (6) COM
J4 (9) COM
FROM I/O SENSE ØA COMMUTATION
J4 (4)
J4 (3)
J4 (7) COM
FROM I/O SENSE ØB COMMUTATION
J4 (1)
J4 (2)
J4 (8) COM
FROM I/O SENSE ØC COMMUTATION
+12V
R1 200
R2 200
R3 200
R4 200
R5 200
R6 200
R31 220K
R32 220K
R33 220K
R34 220K
R35 220K
R36 220K
R37 130K
R38 130K
R39 130K
R40 130K
R41 130K
R42 130K
R43 4.7K
R44 4.7K
R45 4.7K
R46 4.7K
R47 4.7K
R48 4.7K
470 pF
U1A
U1B
U1C
U1D
U2A
U2B
U2C
U2D
U3A
U3B
U3C
U3D
U4A
U4B
U4C
U4D
C49 .01
SEE NOTE B
NC
CN1 CN2 CN7
CN3 CN4 CN9
CN5 CN6 CN11
SEE NOTES ON SHEE
01-211 (rev 2-87)



REV D 8-19-82
REV C 9-4-80 G.H.B
REV B 5 JUN 1979 R.N. Barrett

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO.
MATERIAL	DSGN G.H.B. 3/22/79
	CHECKER R.N. Barrett 3/22/79
	APPD
NEXT ASSY / USED ON / CHG CONTROL	USAF ACTIVITY APPD / OTHER APPROVAL

Delco Electronics

GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF

TITLE: 15KW FREQUENCY CHANGER CONVERTER GATE CONTROL (TQ PROT.)

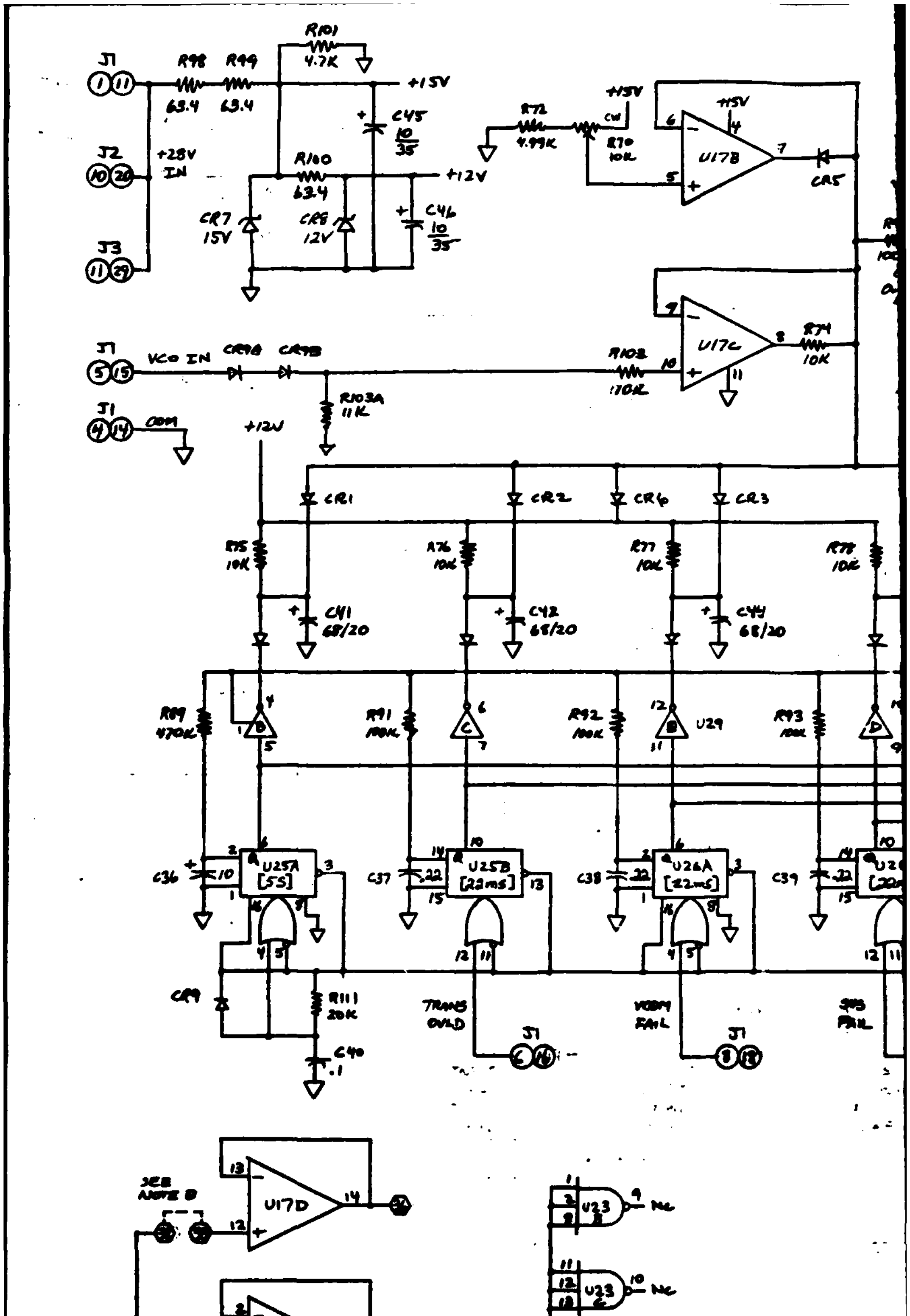
SIZE	CODE IDENT NO.	DWG NO.	REV
C	13160	SK002142	D

SCALE / WEIGHT

NOTES ON SHEET 3

2 2 1

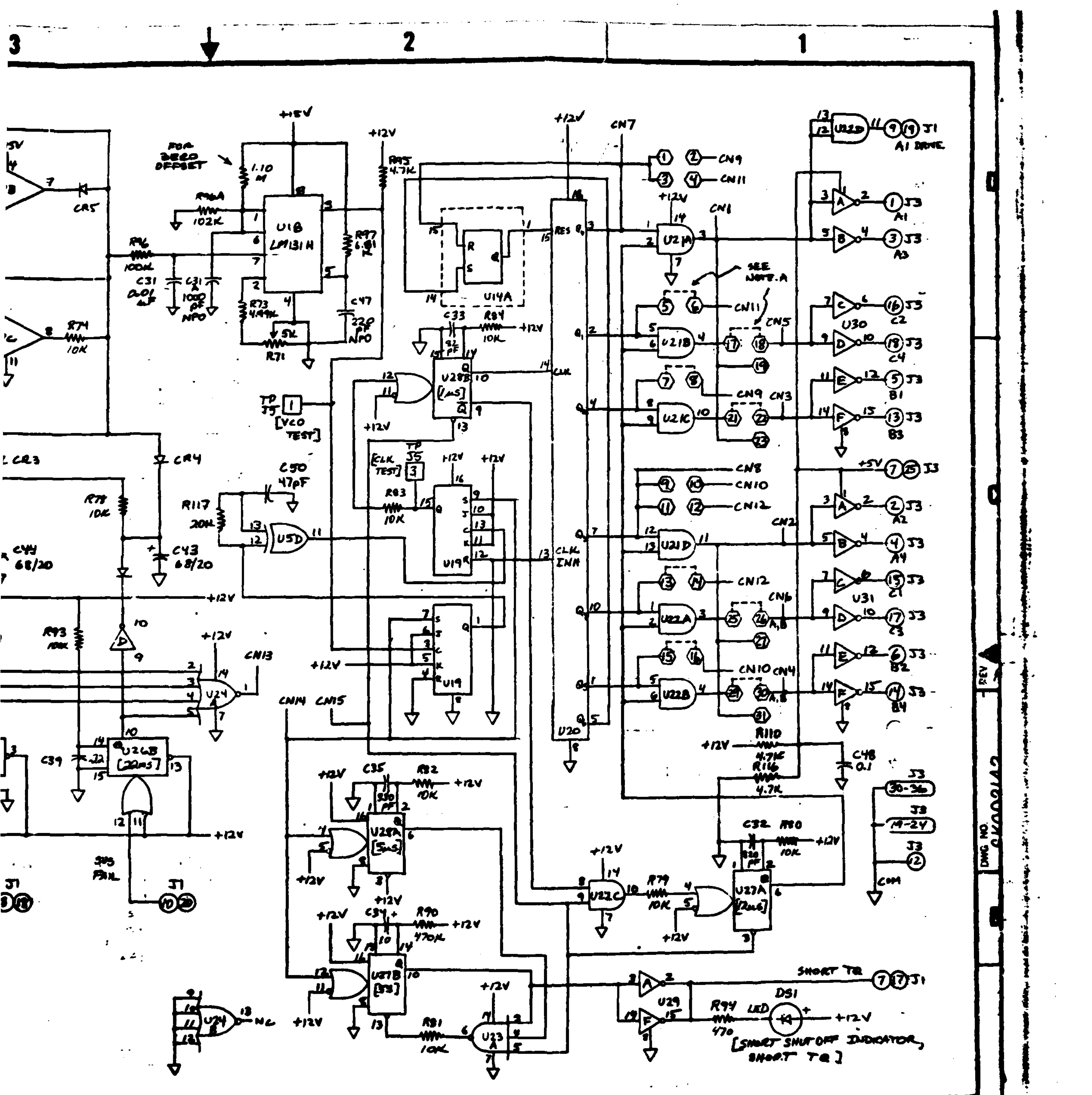
N-6a



NOTE C: COMPONENT DESIG... C1-C50, R1-R117, U1-U...

NOTE B: INSTALL JUMPERS AS INDICATED WITH DAS...

NOTE A: FOR NORMAL MODE (STAGGED FIRING) OPERATION, INSTALL ... AS SHOWN WITH DASHED LINES (IE, E5 TO E6, E7 TO E8, E... MODE (SIMULTANEOUS FIRING) OPERATION, DELETE NORMA... THE FOLLOWING JUMPERS: E1 TO E2, E3 TO E4, E9 TO... E22 TO E23, E26 TO E27, E30 TO E31.



COMPONENT DESIGNATIONS ARE:
R1-R117, U1-U31, DS1

...DICATED WITH DASHED LINES.

...PERATION, INSTALL JUMPERS BETWEEN E POINTS ...TO E6, E7 TO E8, E13 TO E14, ETC.). FOR ALTERNATE ...N, DELETE NORMAL MODE JUMPERS AND ADD ..., E3 TO E4, E9 TO E10, E11 TO E12, E18 TO E19, ...D E31.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON: 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO.	
MATERIAL	DFTSMN G.H.B. 3/27/78	
	CHECKER	
	A.H. Barrett 3/27/78	
	APPD	
	APPD	
REF (ACDAL) CHG CONTROL	USGN ACTIVITY APPD	
	OTHER APPROVAL	

Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF

TITLE: 15KW FREQUENCY CHANGER VCO AND CONV GATE CONTROL

SIZE	CODE IDENT NO.	DWG NO.	REV
C	13160	SK002142	D

SCALE | WEIGHT

3 2 1

N-6B

4

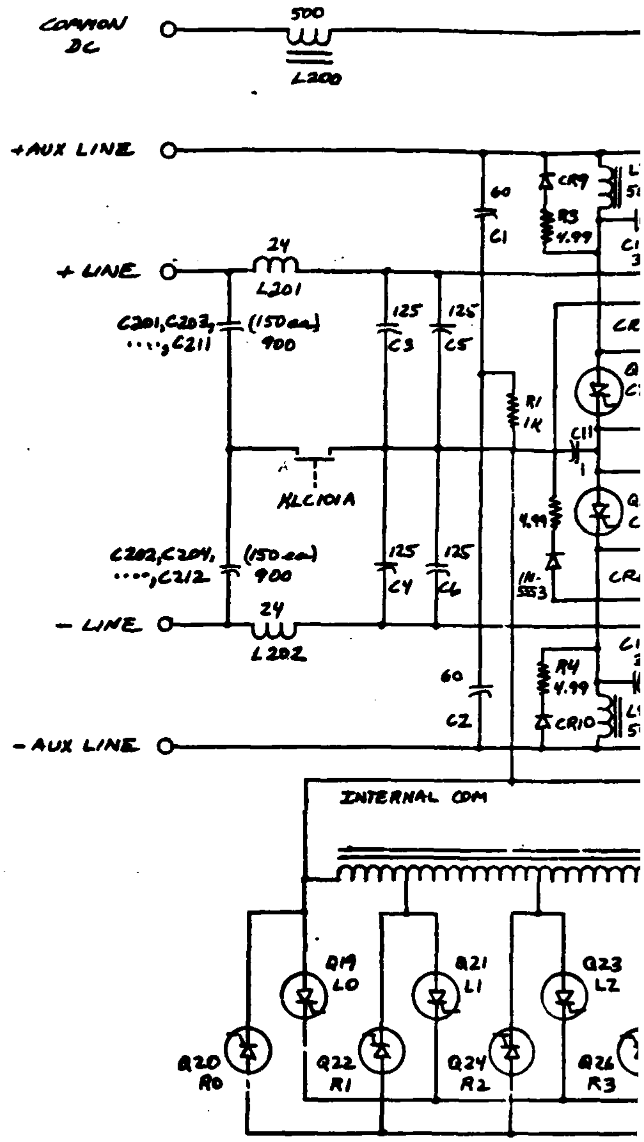
3

D

C

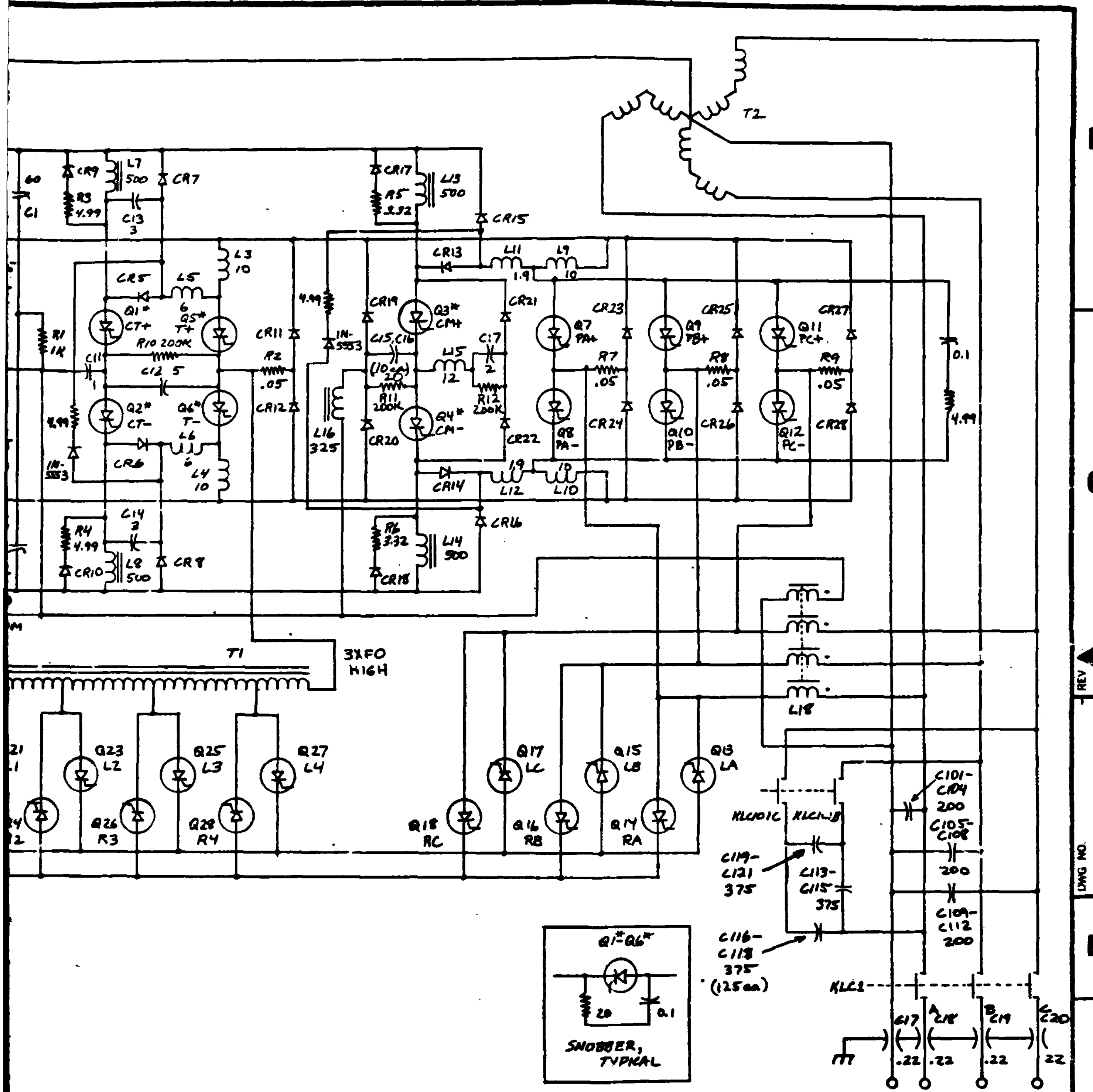
B

A


COMMON DC
500
L200
+AUX LINE
+LINE
24
L201
C201,C203,....,C211
(150 ea.) 900
125
C3
125
C5
60
C1
CR9
R3 4.99
R1 1K
C11
HLC101A
C202,C204,....,C212
(150 ea.) 900
125
C4
125
C6
4.99
1N-5553
- LINE
24
L202
60
C2
R4 4.99
CR10
- AUX LINE
INTERNAL COM
Q19 L0
Q21 L1
Q23 L2
Q20 R0
Q22 R1
Q24 R2
Q26 R3

4

3



28 SCR, BASE LINE

Rev B C.H. Barrett 9-2-80
added snubbers

NOTE D: * DENOTES SCR WITH SNUBBER
NOTE C: RESISTANCE VALUES IN OHMS
NOTE B: INDUCTANCE VALUES IN µH
NOTE A: CAPACITANCE VALUES IN µF

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
2 PLACE DECIMALS ± | 3 PLACE DECIMALS ± | ANGLES ±

MATERIAL

REF (AC) DRL: DO6 | CHG CONTROL

DRAWN: C.H.B. 11/30/77
CHECKER
ENGR: C.H. Barrett 11/30/77
APPD
APPD
USGN ACTIVITY APPD
OTHER APPROVAL

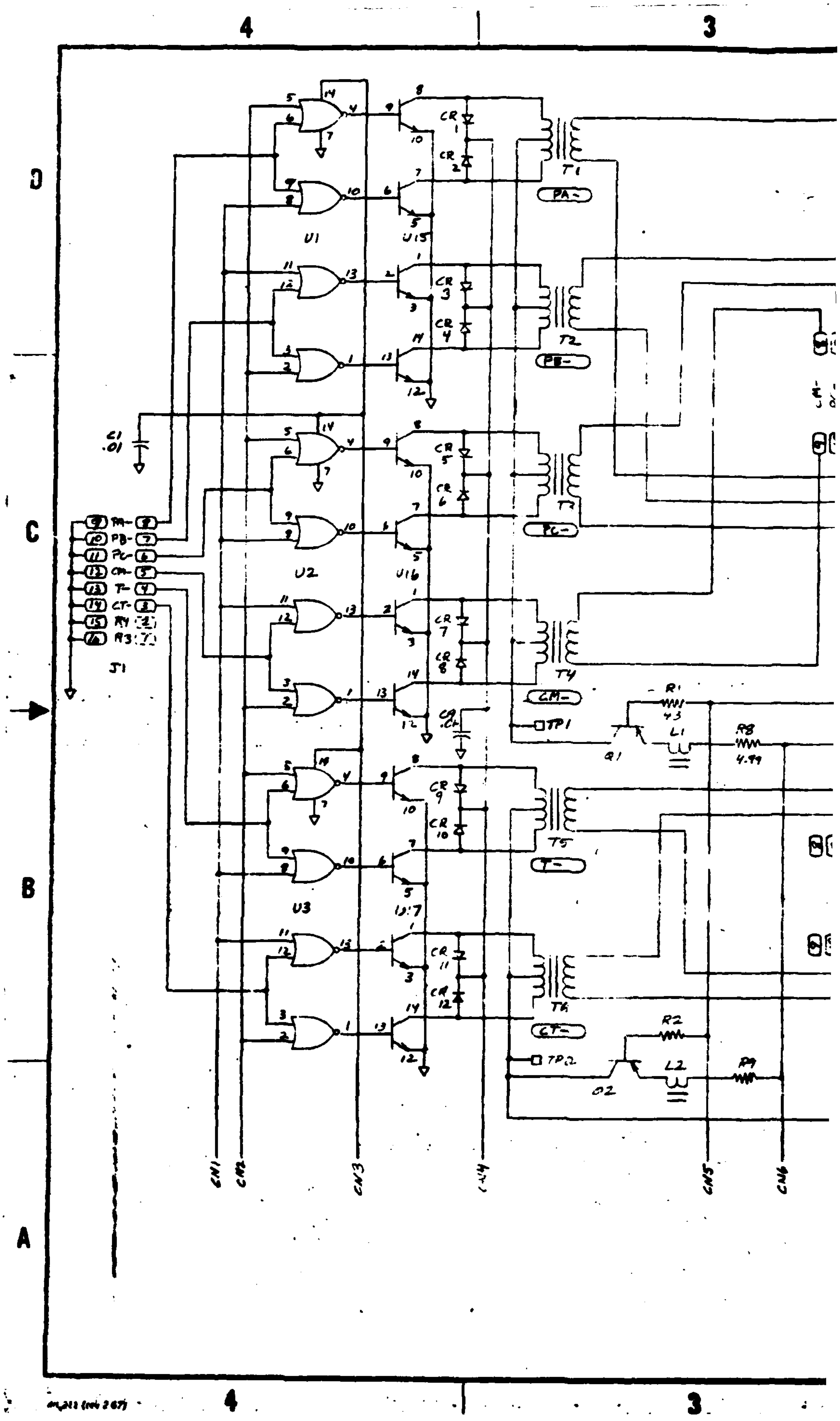
Delco Electronics
GENERAL MOTORS CORPORATION · SANTA BARBARA, CALIF.

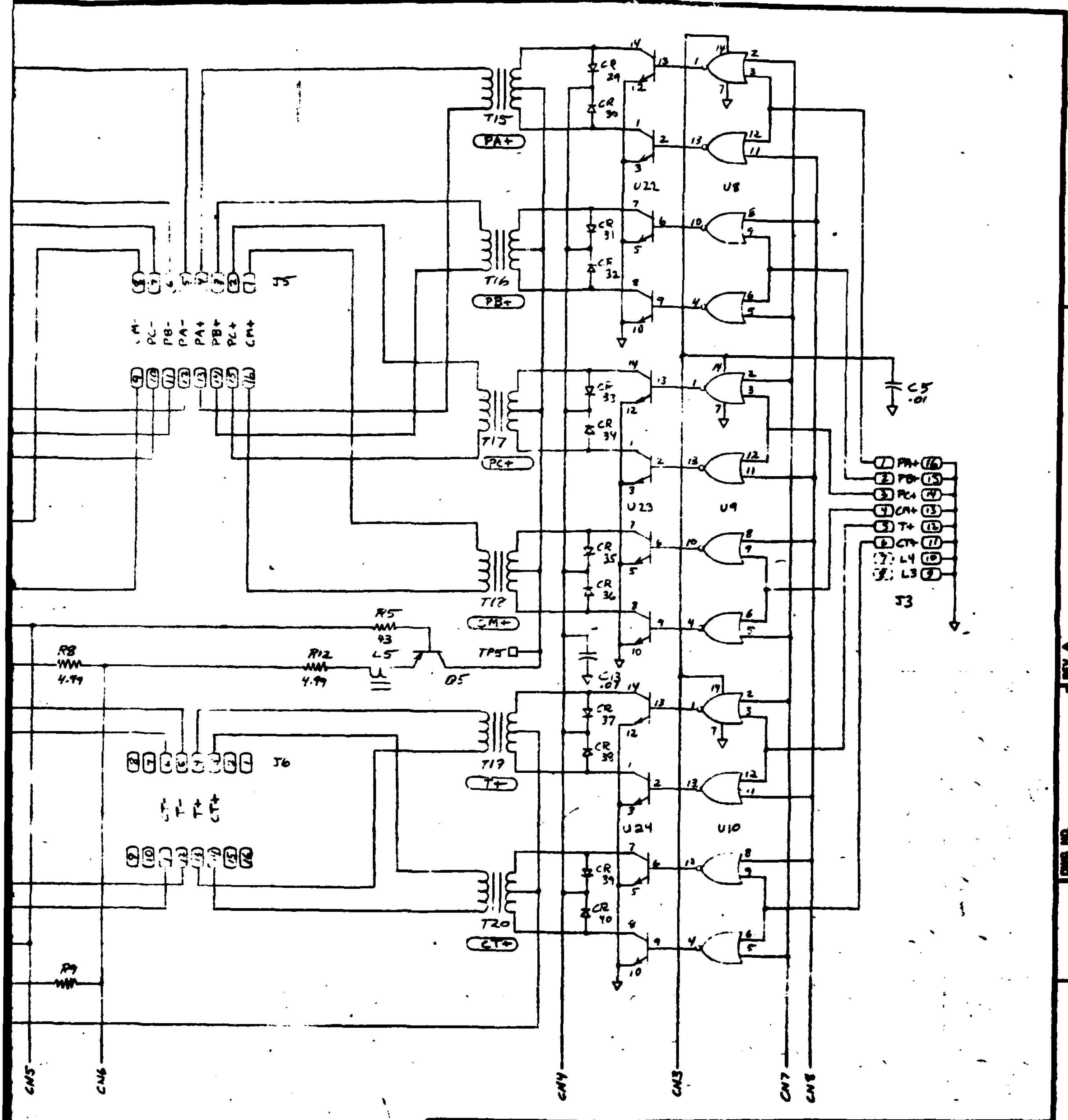
10/400 HZ FIXED COMPENSATION (BASE LINE) INVERTER SCHEMATIC 15KW FREQUENCY CHANGER

SIZE	CODE IDENT NO.	DWG NO.	REV
C	13160	SK 002136	B

SCALE | WEIGHT | SHEET 1 OF 1

N-7

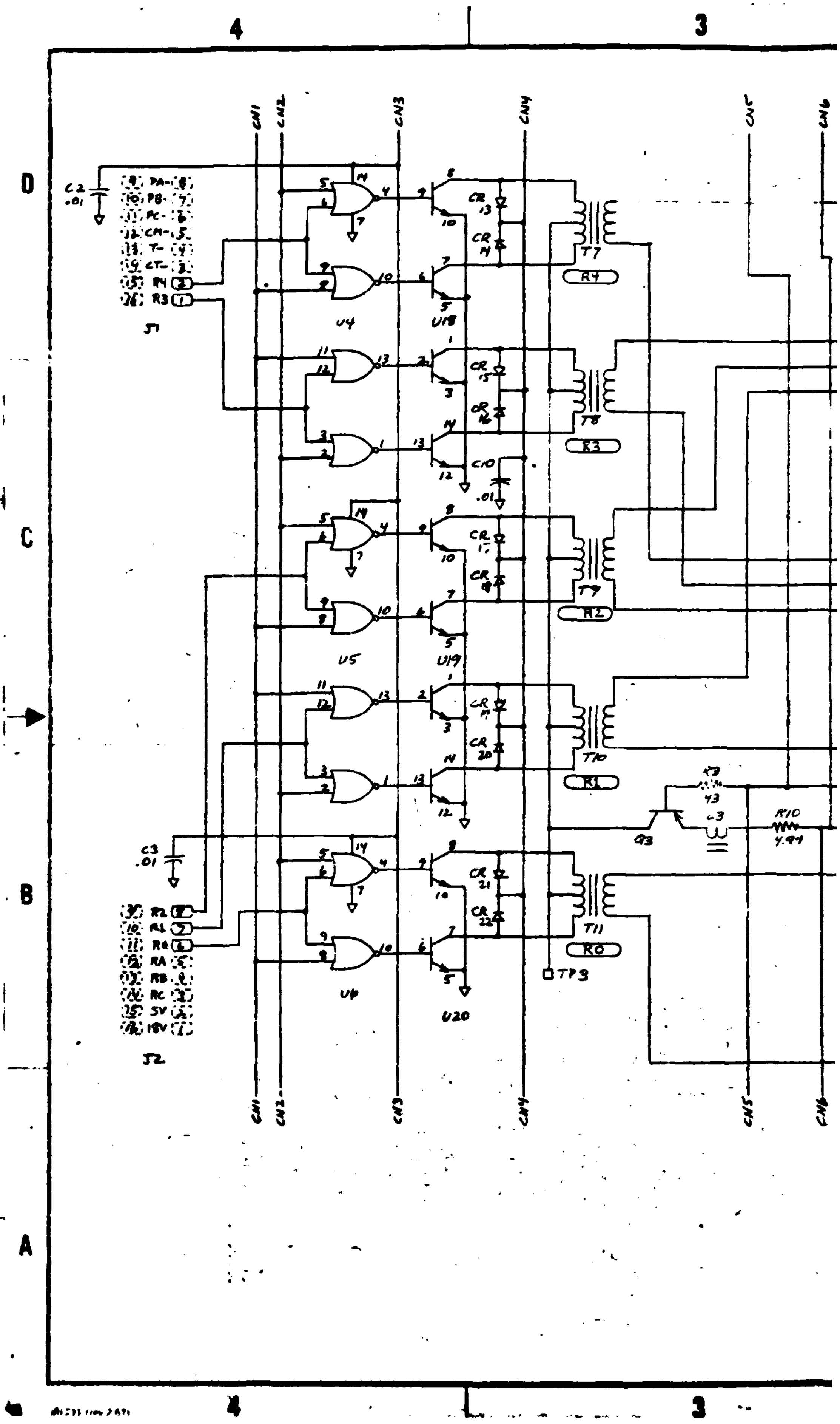

U1
U15
U2
U16
U3
T1
T2
T4
T5
PA-
PB-
PC-
CM-
T-
CT-
J1
C1
.01
R1
43
R2
R8
4.99
R9
L1
L2
Q1
Q2
TP1
TP2
CN1
CN2
CN3
CN5
CN6



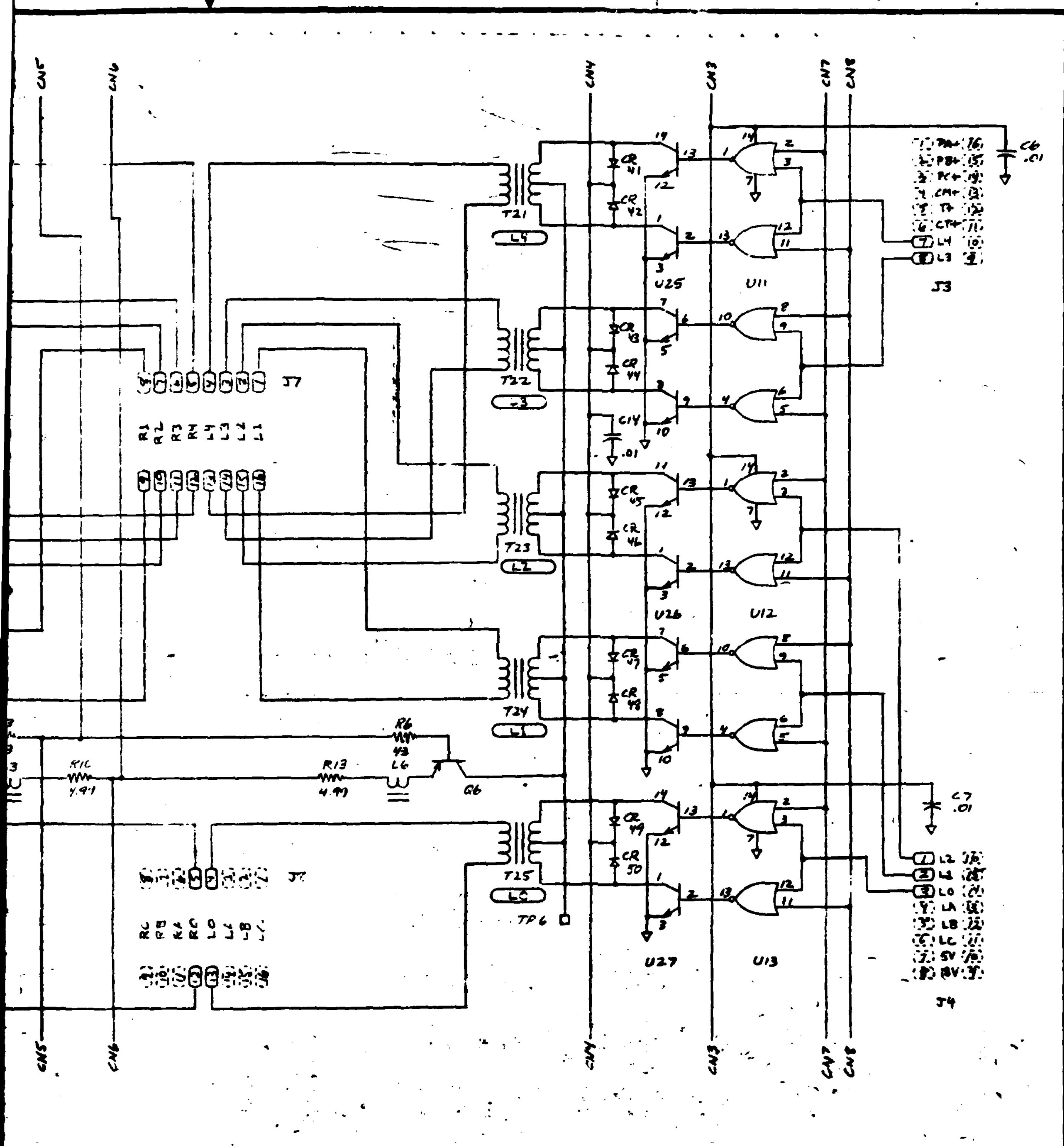
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTRACT	Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
MATERIAL	DFTSMN DSGR G.H.B. 11/25/75	TITLE SCR DRIVER SCHEMATIC
	CHECKER	
	ENGR G.H. Barrett 11/25/75	
	APPD	SIZE C · CODE IDENT NO 13160 · DWG NO. SK002210 · REV 5
NEXT ASSY / USED ON · CHG CONTROL	DSGN ACTIVITY APPR. · OTHER APPROVAL	SCALE · WEIGHT

Rev B A.H Barrett 9-2-80

N-8A

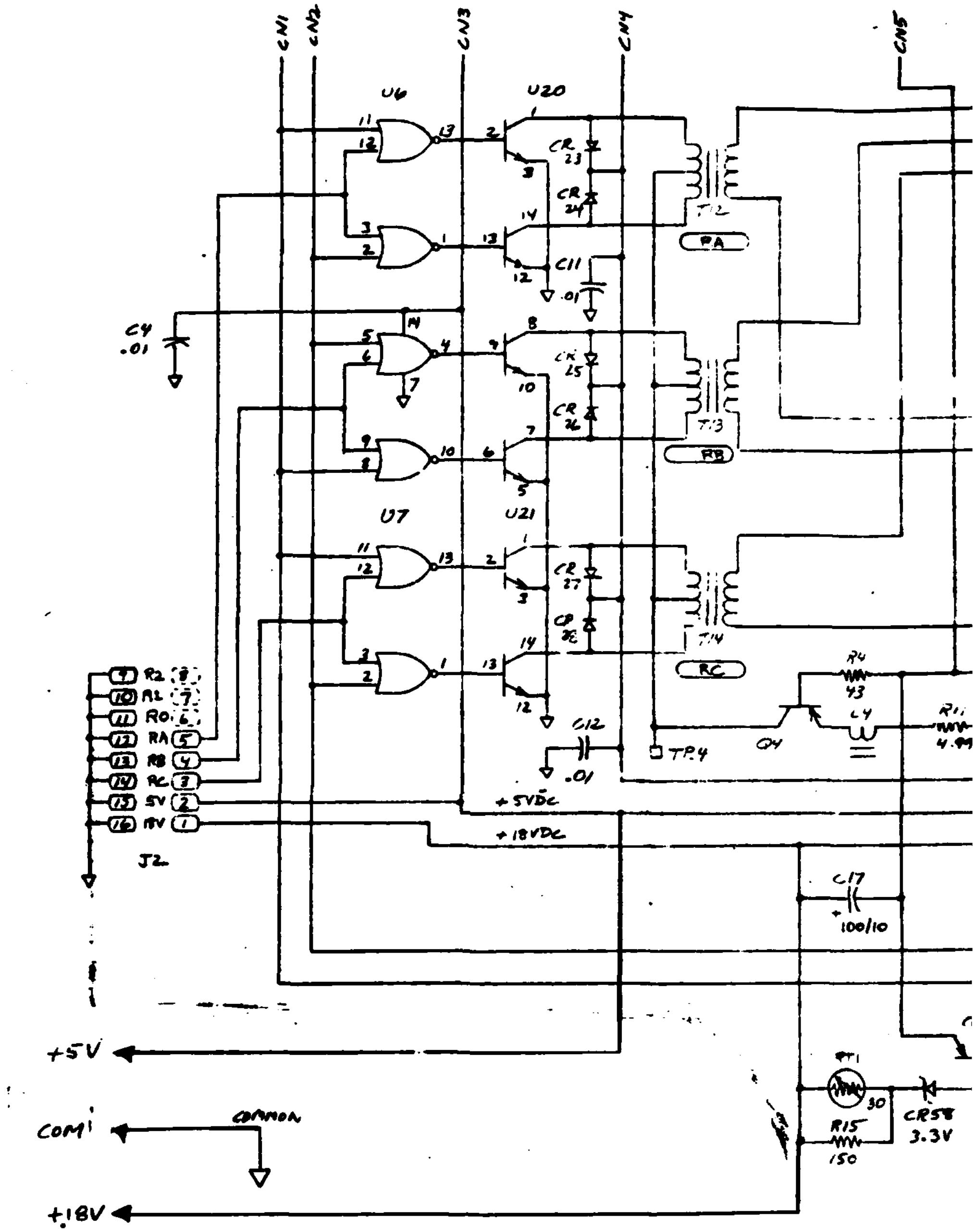


4
3
D
C
B
A
CN1
CN2
CN3
CN4
CN5
CN6
C2 .01
C3 .01
C10 .01
J1
J2
U4
U5
U6
U18
U19
U20
T7
T8
T9
T10
T11
R4
R3
R2
R1
R0
TP3
Q3
R10 4.99
CR13
CR14
CR15
CR16
CR17
CR18
CR19
CR20
CR21
CR22
PA-
PB-
PC-
CM-
T-
CT-
RA
RB
RC
5V
18V

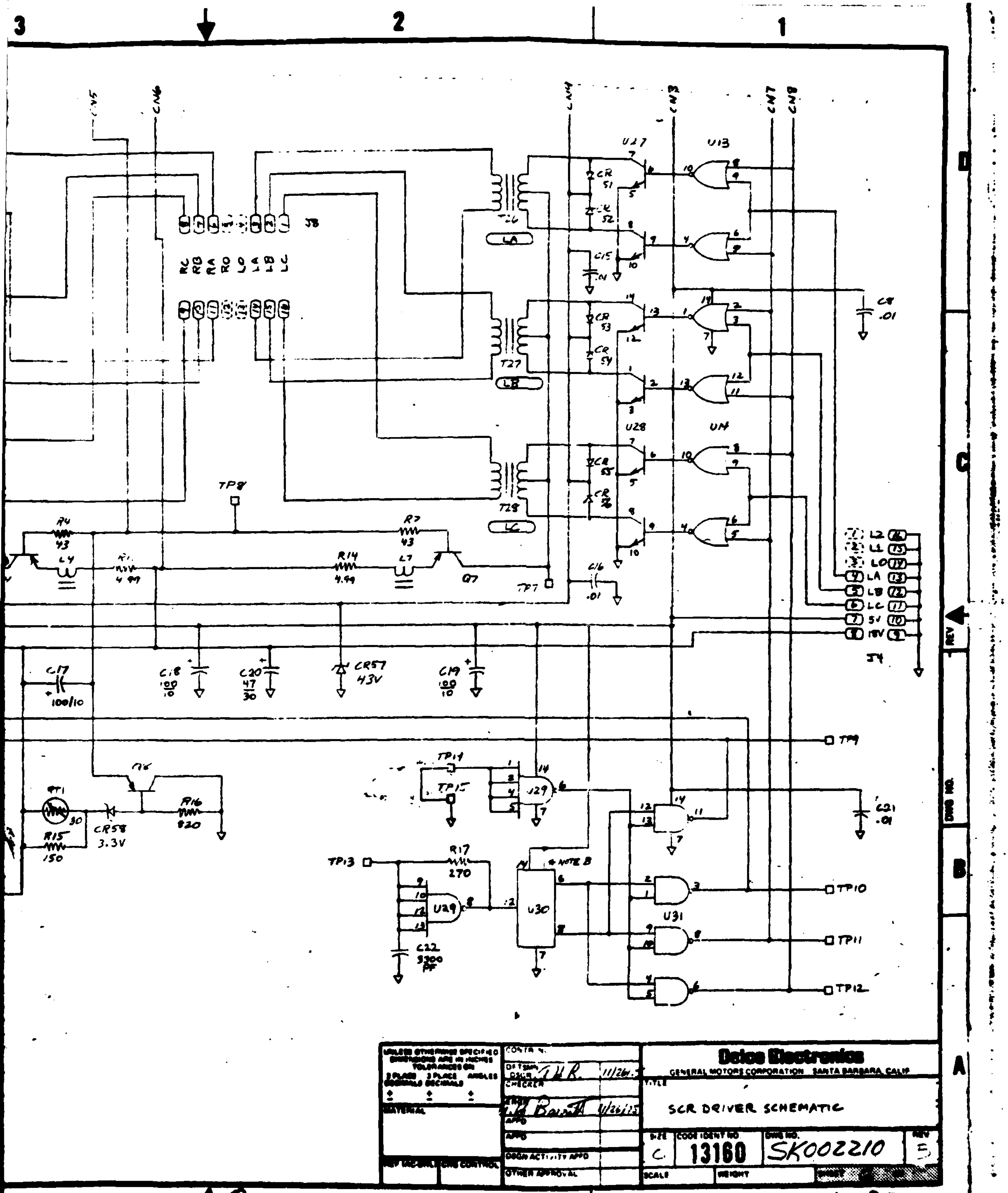


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO	**Delco Electronics** GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
MATERIAL	DFTSMN DSGR GHB 11/25/75	TITLE SCR DRIVER SCHEMATIC
	CHECKER	
	ENGR 11/25/75	
	APPD	
	APPD	SIZE C · CODE IDENT NO 13160 · DWG NO SK002210 · REV 3
NEXT ASSY USED ON	DSGN ACTIVITY APPD	
	OTHER APPROVAL	SCALE · WEIGHT

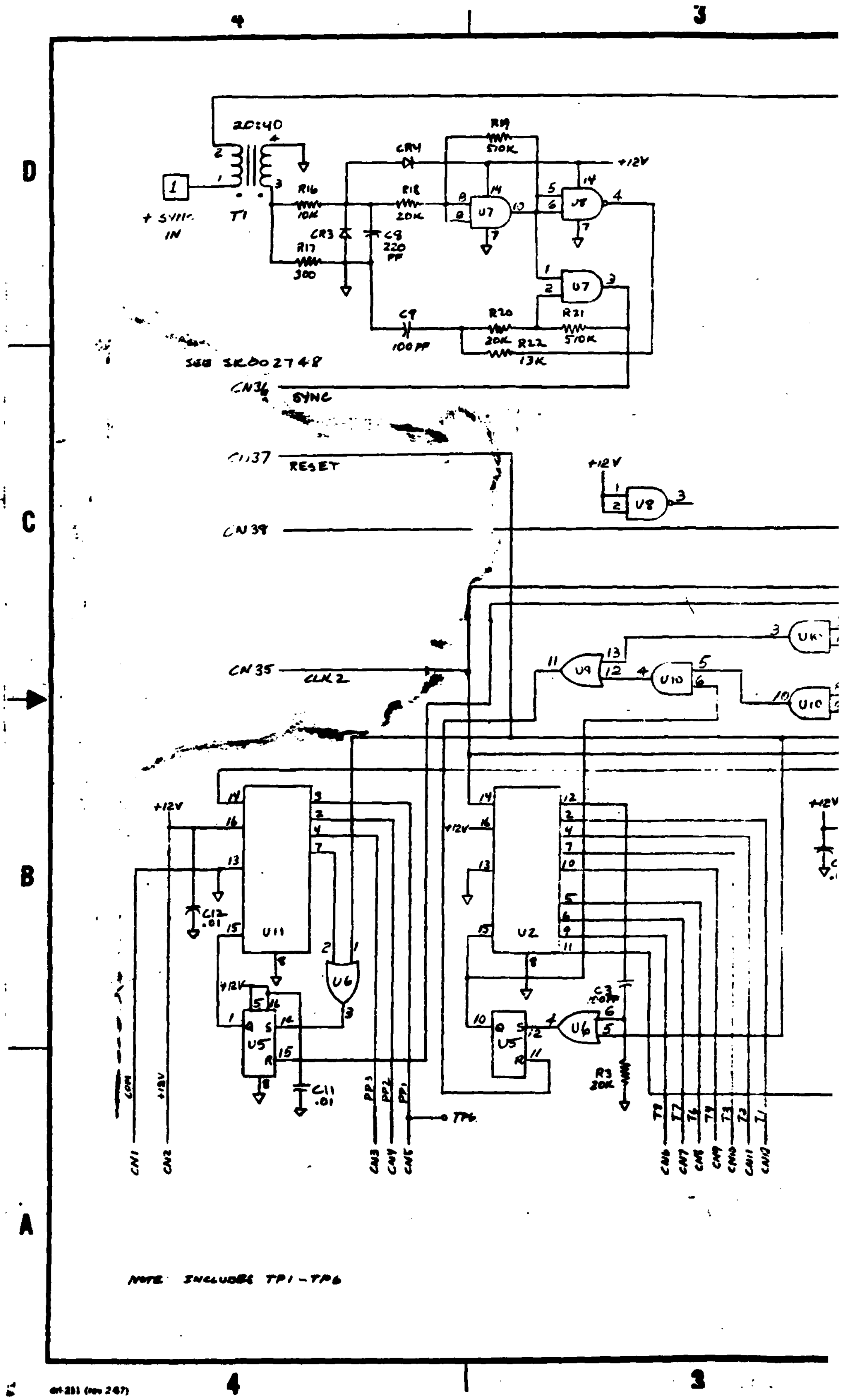
N-88



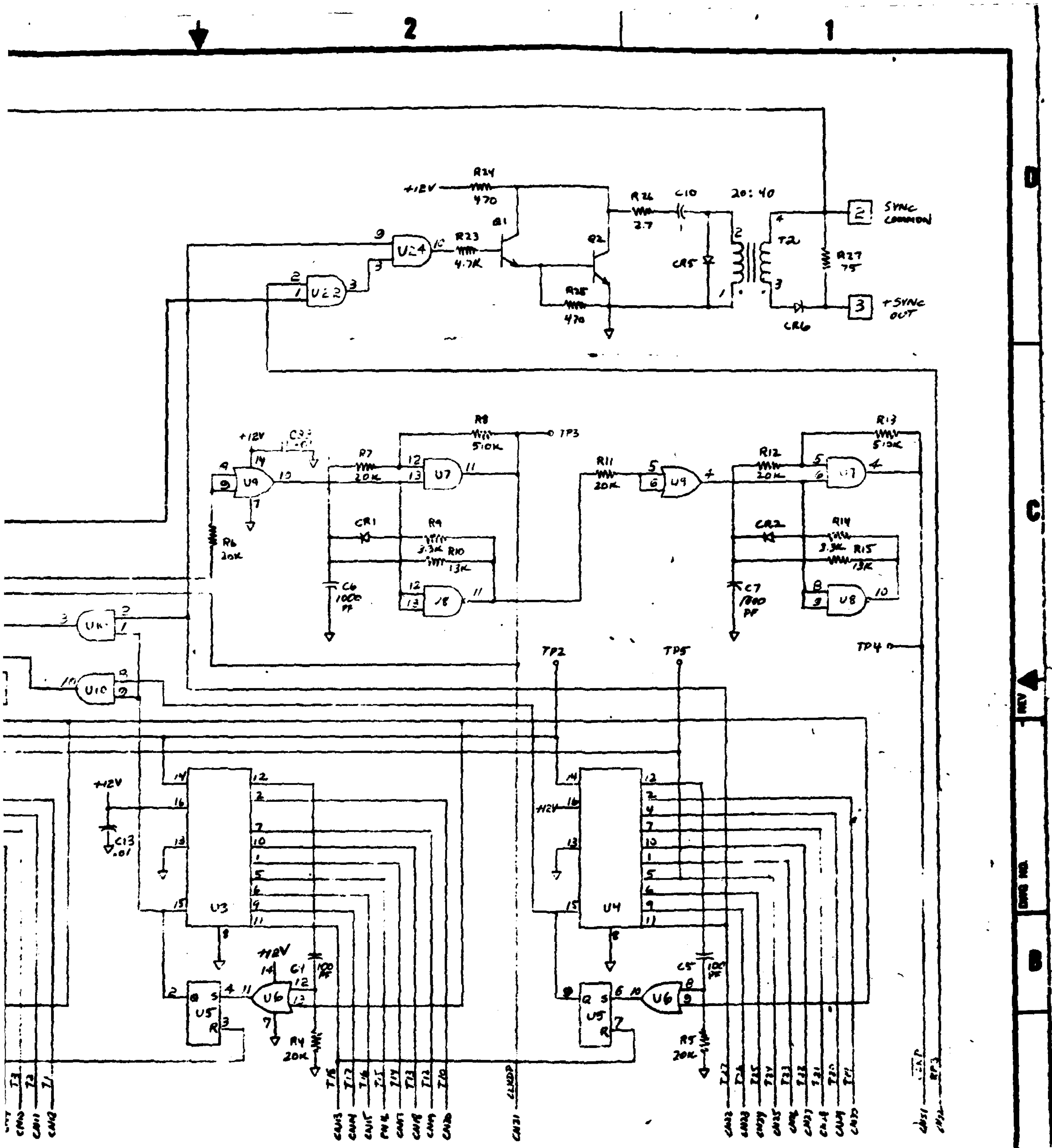
RT601
C601 – C621
CR601 – CR658
L601 – L607
T601 – T628
Q601 – Q608
R601 – R617
TP601 – TP615
U601 – U631



SCR DRIVER SCHEMATIC
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
MATERIAL
CONTR NO.
DFTSMN
CHECKER
APPD
DSGN ACTIVITY APPD
OTHER APPROVAL
SIZE C
CODE IDENT NO 13160
DWG NO. SK002210
REV 5
SCALE
WEIGHT
N-8C
J8
J4
U27
U13
U28
U14
U29
U30
U31
T26
T27
T28
LA
LB
LC
Q7
TP7
TP8
TP9
TP10
TP11
TP12
TP13
TP14
TP15
CR57 43V
CR58 3.3V
R16 820
R15 150
R17 270
C22 3300 PF
C8 .01
C21 .01
C16 .01
C17 100/10
C18 100 10
C20 47 30
C19 100 10
R4 43
R7 43
R14 4.99
NOTE B



4
3
D
C
B
A
20:40
T1
+ SYNC IN
R16 10K
R17 300
R18 20K
R19 510K
CR4
CR3
C8 220 PF
+12V
U7
U8
C9 100 PF
R20 20K
R21 510K
R22 13K
SEE SK002748
CN36 SYNC
CN37 RESET
CN39
CN35 CLK 2
U9
U10
U11
U2
U5
U6
C12 .01
C11 .01
C3
R3 20K
TP6
CN1
CN2
CN3
CN4
CN5
PP1
PP2
PP3
NOTE INCLUDES TP1 - TP6



REV C 8-20-82 JRC

Rev B. G K Barrett 5-3-80

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS 3 PLACE DECIMALS ANGLES ± ± ±	CONTR NO	
MATERIAL	DFTSMN K.B. CHECK	DEC 75
	CHECKER	
	ENGR G K Barrett	DEC 22-75
	APPD	
	APPD	
	DESIGN ACTIVITY APPD	
	OTHER APPROVAL	

Delco Electronics

GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF

TITLE WAVEFORM GENERATOR

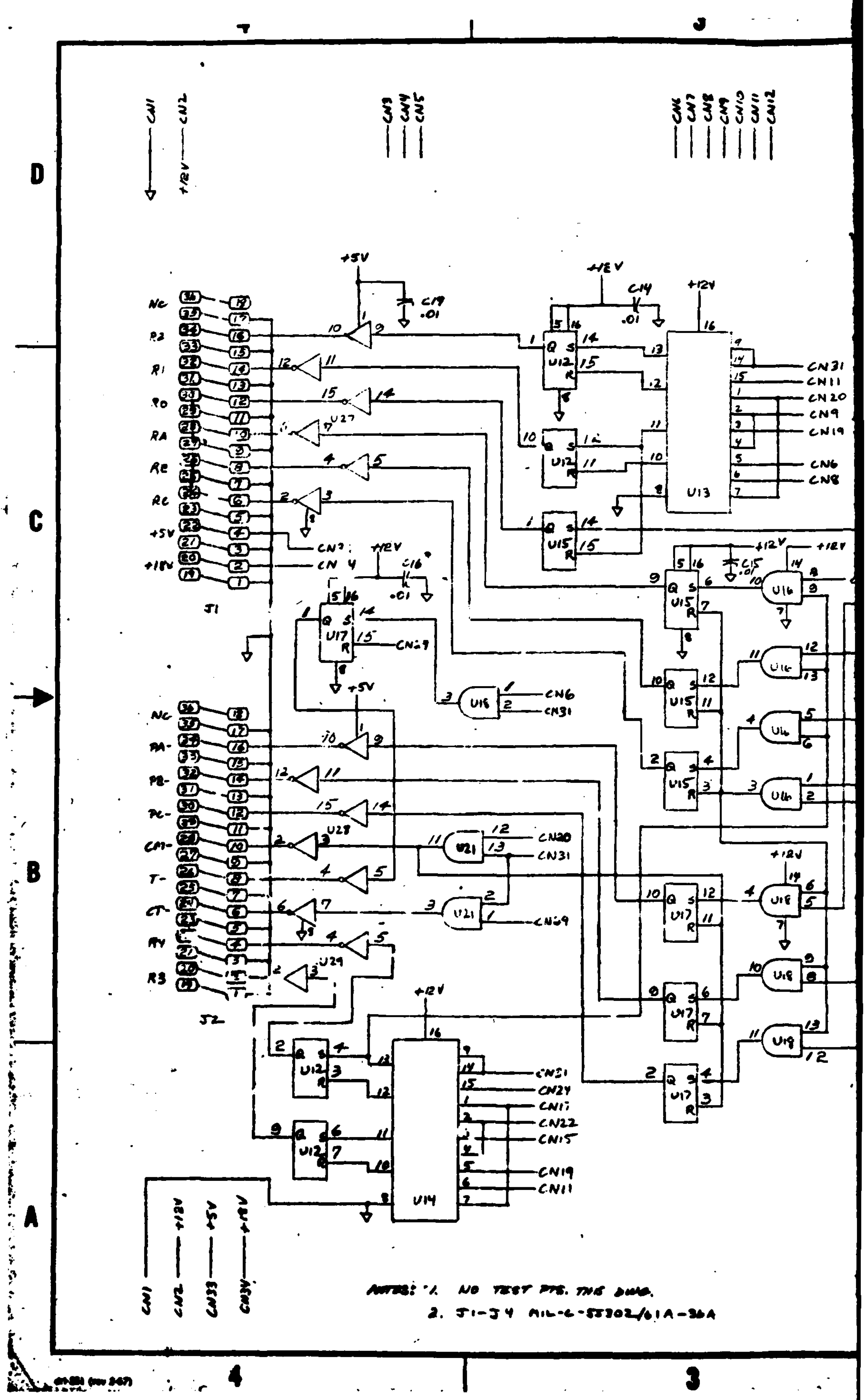
SYNC AND COUNTERS

SIZE	CODE IDENT NO.	DWG NO.	REV
C	13160	SK002211	–

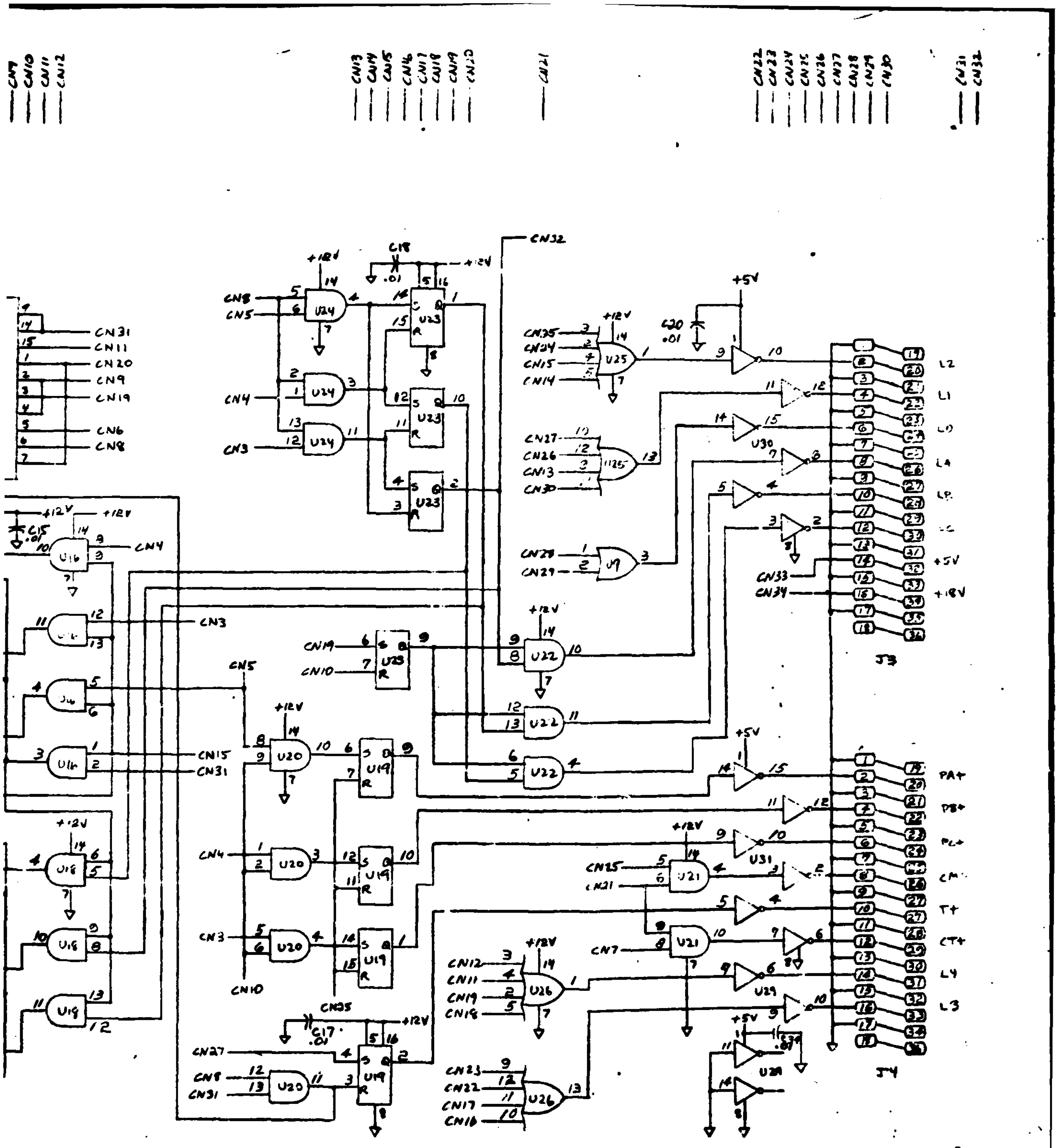
SCALE | WEIGHT

2 | 1

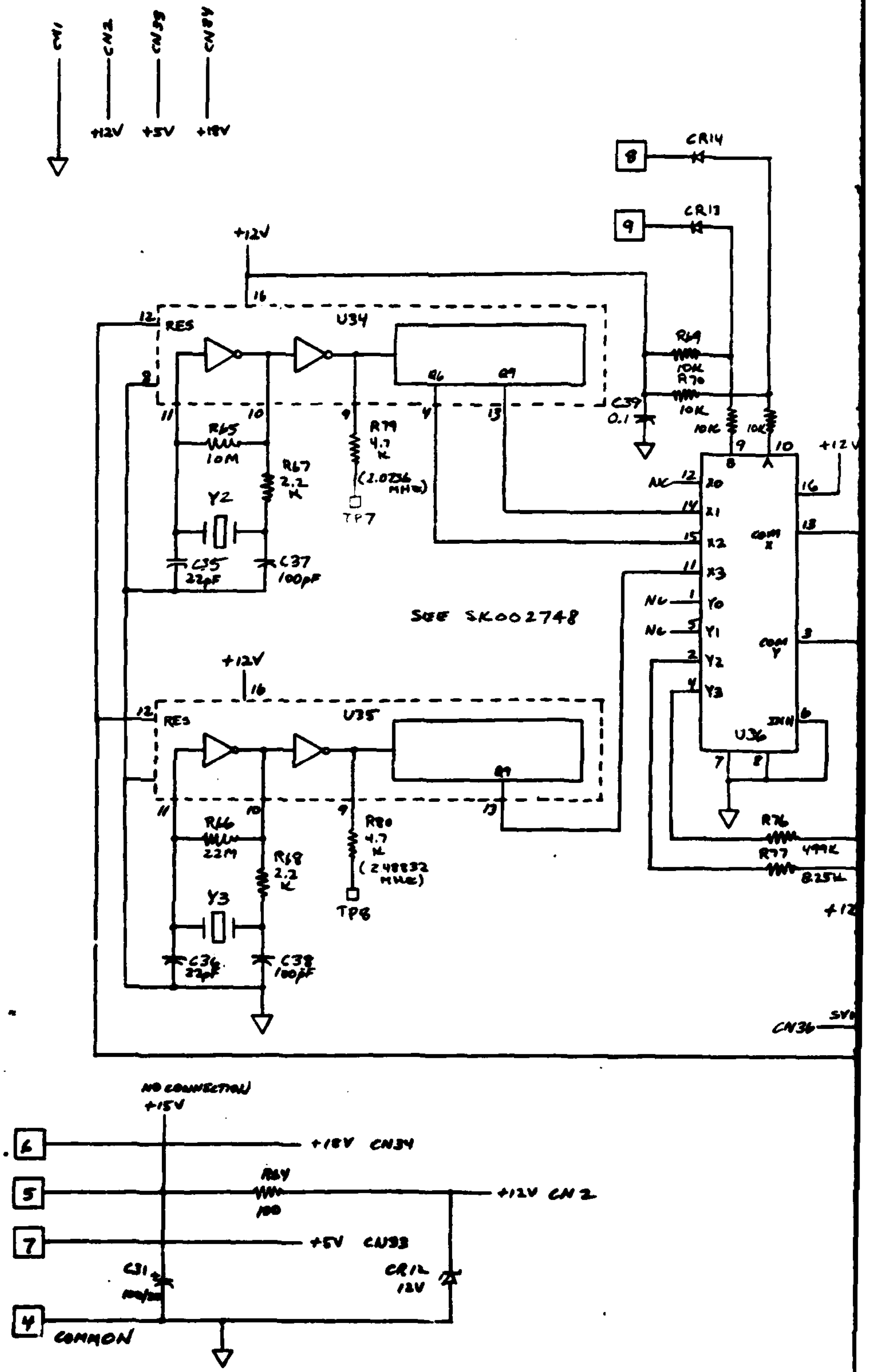
N-9A



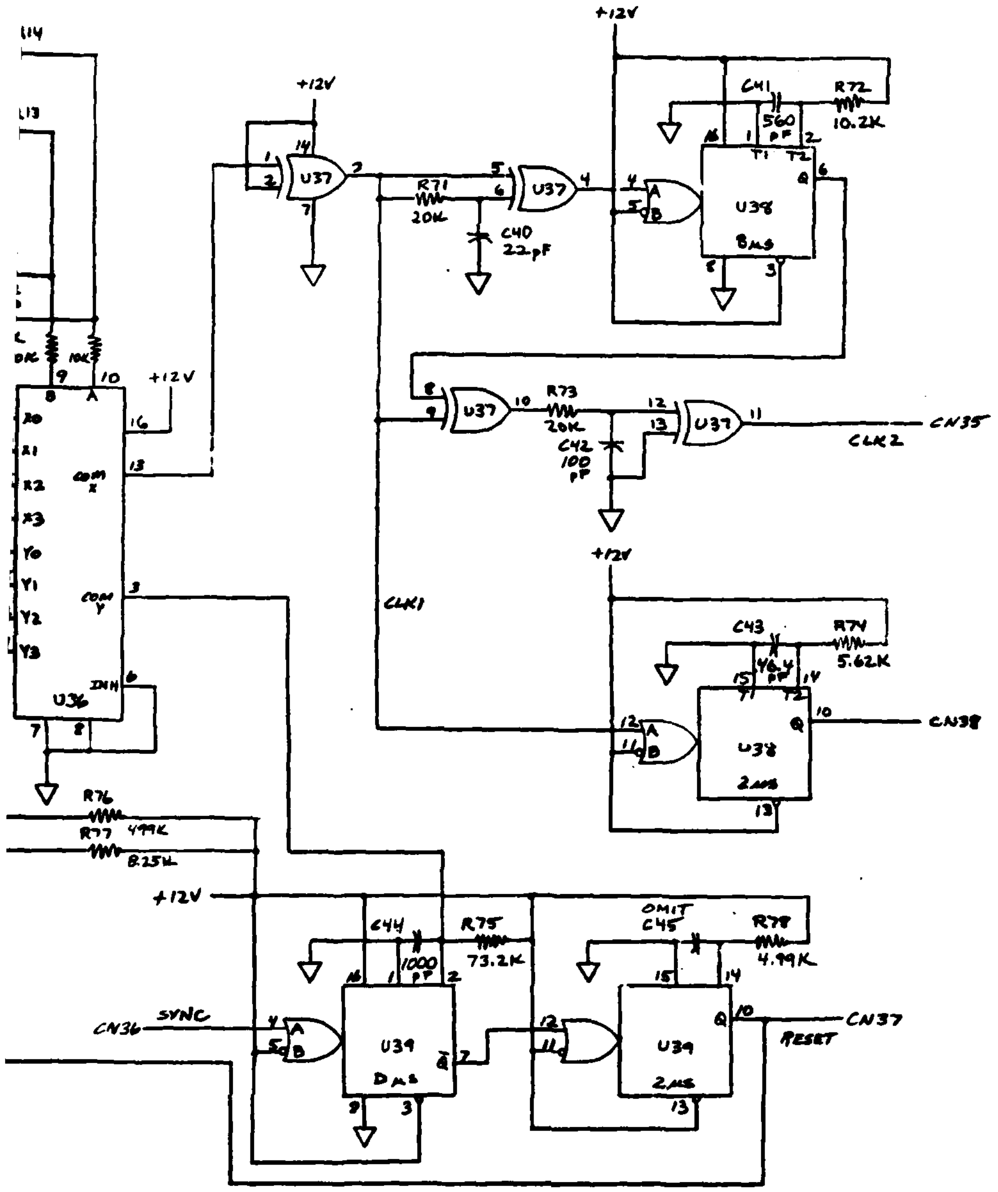
NOTES: 1. NO TEST PTS. THIS DWG.
2. J1-J4 MIL-C-55302/61A-36A
J1
J2
U12
U13
U14
U15
U16
U17
U18
U21
U27
U28
U29
+5V
+12V
+18V



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS 3 PLACE DECIMALS ANGLES ± ± ±	CONTR. NO.		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.
MATERIAL	DFTSMN / DSGN G.W.B	DEC 23-75	TITLE - WAVEFORM GENERATOR
	CHECKER		DECODERS AND BUFFERS
	ENGR A.H. Bennett	DEC 23-75	
	APPD		SIZE C · CODE IDENT NO. 13160 · DWG NO. SK002211 · REV
	APPD		
	DSGN ACTIVITY APPD		
REF DESIGNATIONS CONTROL	OTHER APPROVAL		SCALE · WEIGHT · SHEET OF



NOTE: □ DENOTES CONNECTION ON THE TERMI
BLOCK A2TB1



ON THE TERMINAL

A.K.B. 6/6/78

A.K. Barnett 6/6/78

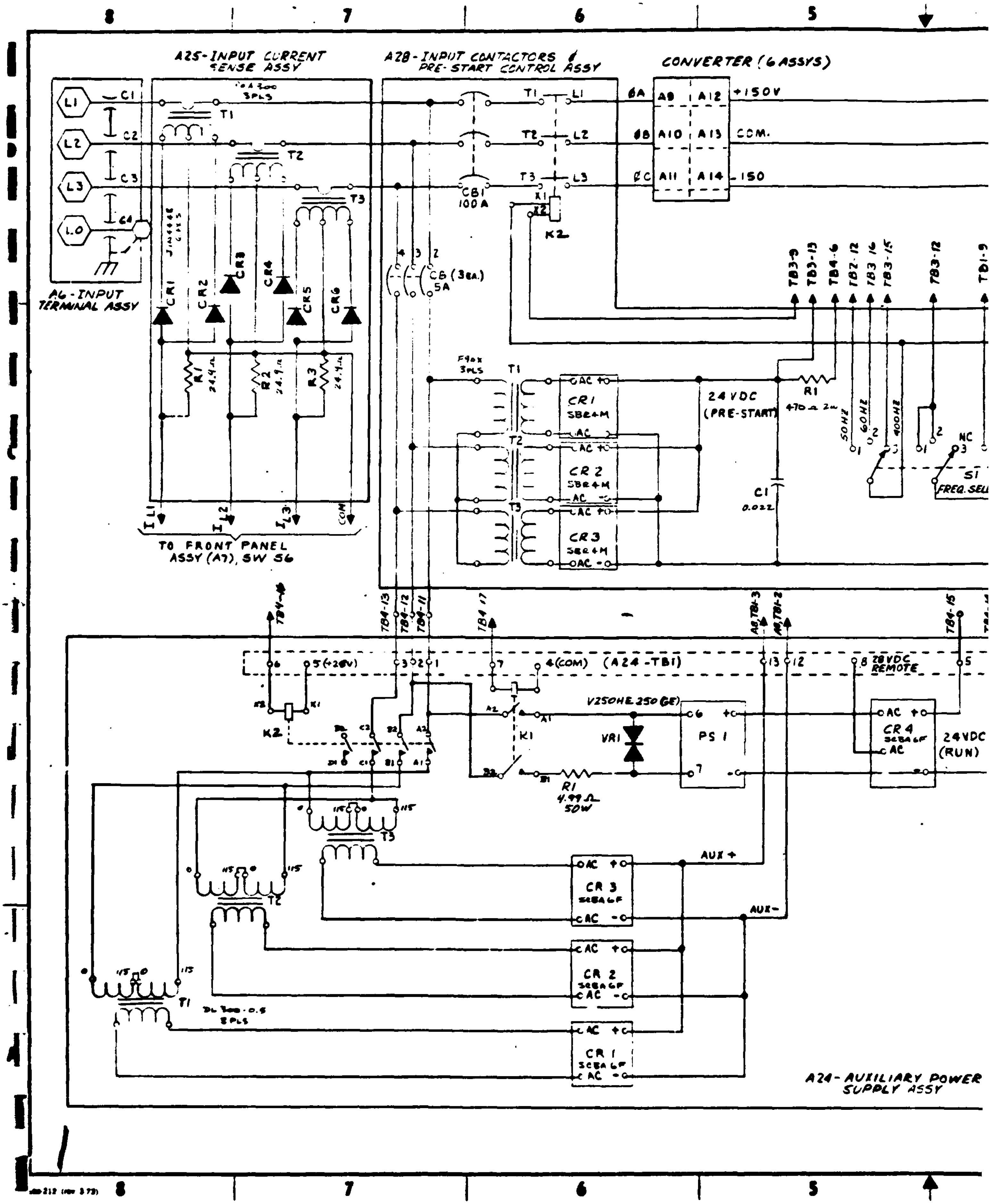
15KW FREQUENCY CHANGER MODIFICATIONS

C

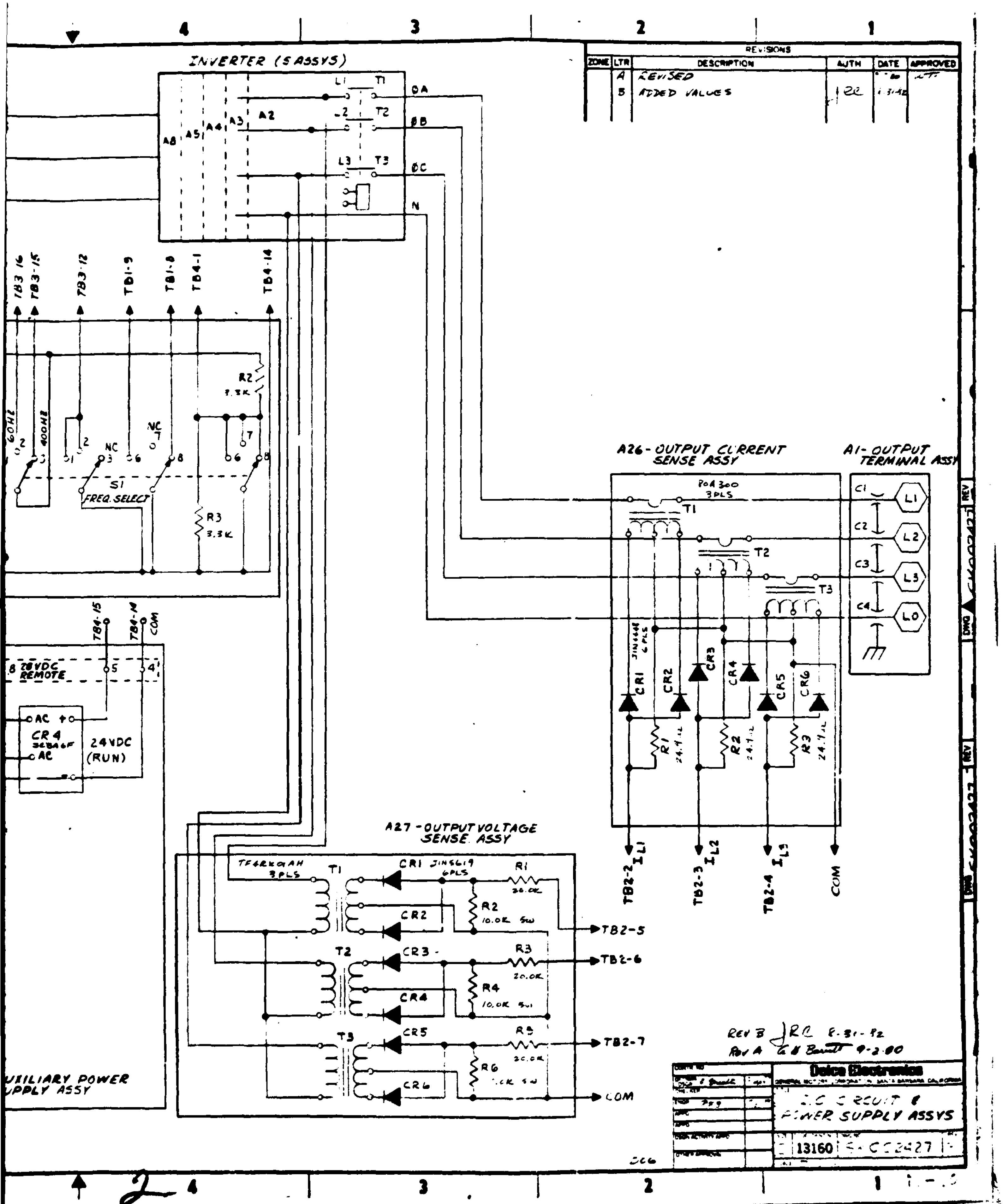
SK002211 C

N-9C

2



A25-INPUT CURRENT SENSE ASSY
A28-INPUT CONTACTORS & PRE-START CONTROL ASSY
CONVERTER (6 ASSYS)
A6-INPUT TERMINAL ASSY
+150V
COM.
-150
CB1 100A
CB (3EA.) 5A
K2
24VDC (PRE-START)
TO FRONT PANEL ASSY (A7), SW S6
S1 FREQ. SEL
50HZ
60HZ
400HZ
(A24-TB1)
5(+28V)
4(COM)
28VDC REMOTE
V250HE 250 (GE)
VR1
PS 1
K1
R1 4.99Ω 50W
24VDC (RUN)
CR 4
CR 3
CR 2
CR 1
AUX +
AUX -
A24-AUXILIARY POWER SUPPLY ASSY



REVISIONS

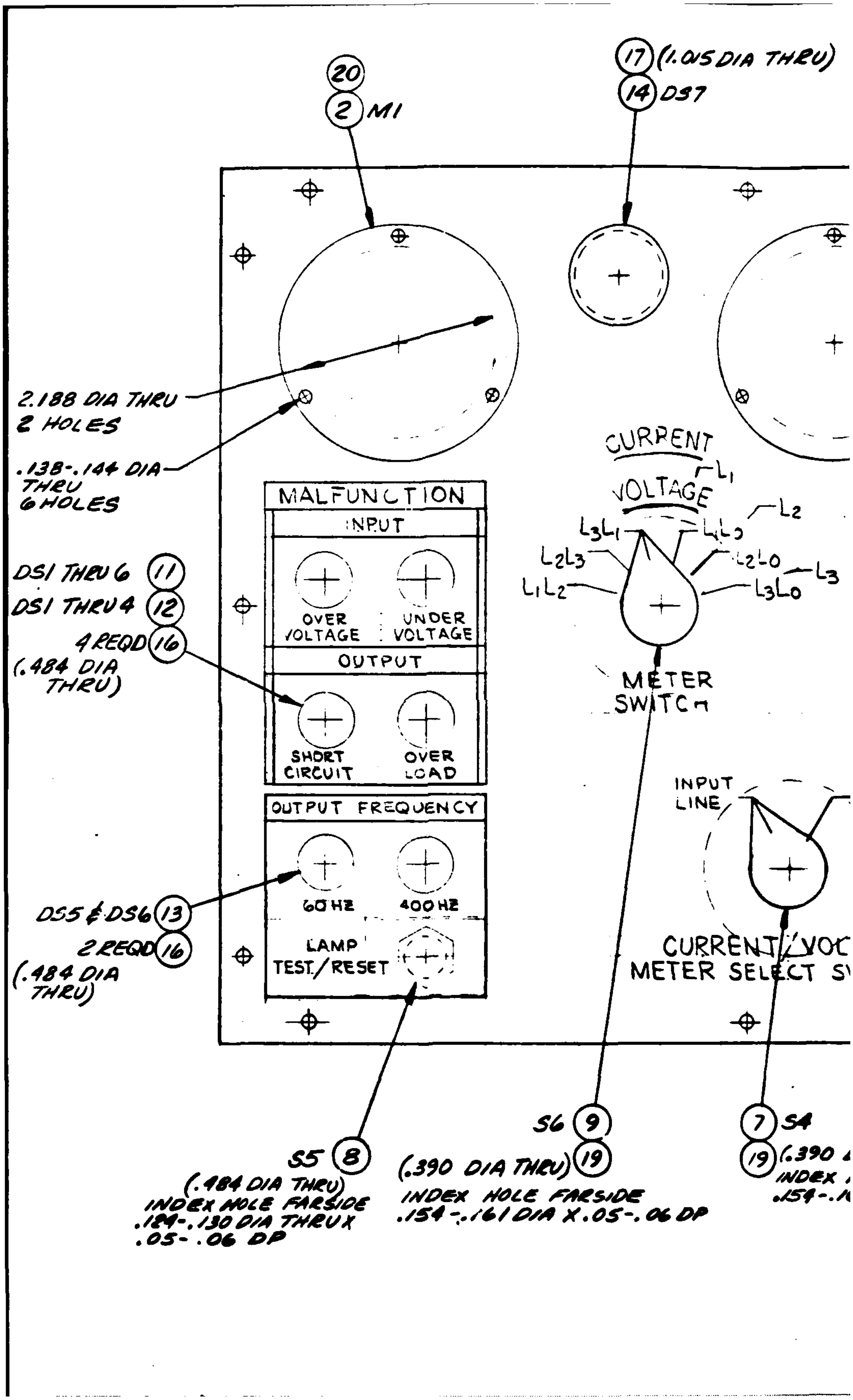
ZONE	LTR	DESCRIPTION	AUTH	DATE	APPROVED
	A	REVISED			
	B	ADDED VALUES			

Delco Electronics

GENERAL MOTORS CORPORATION · SANTA BARBARA, CALIFORNIA

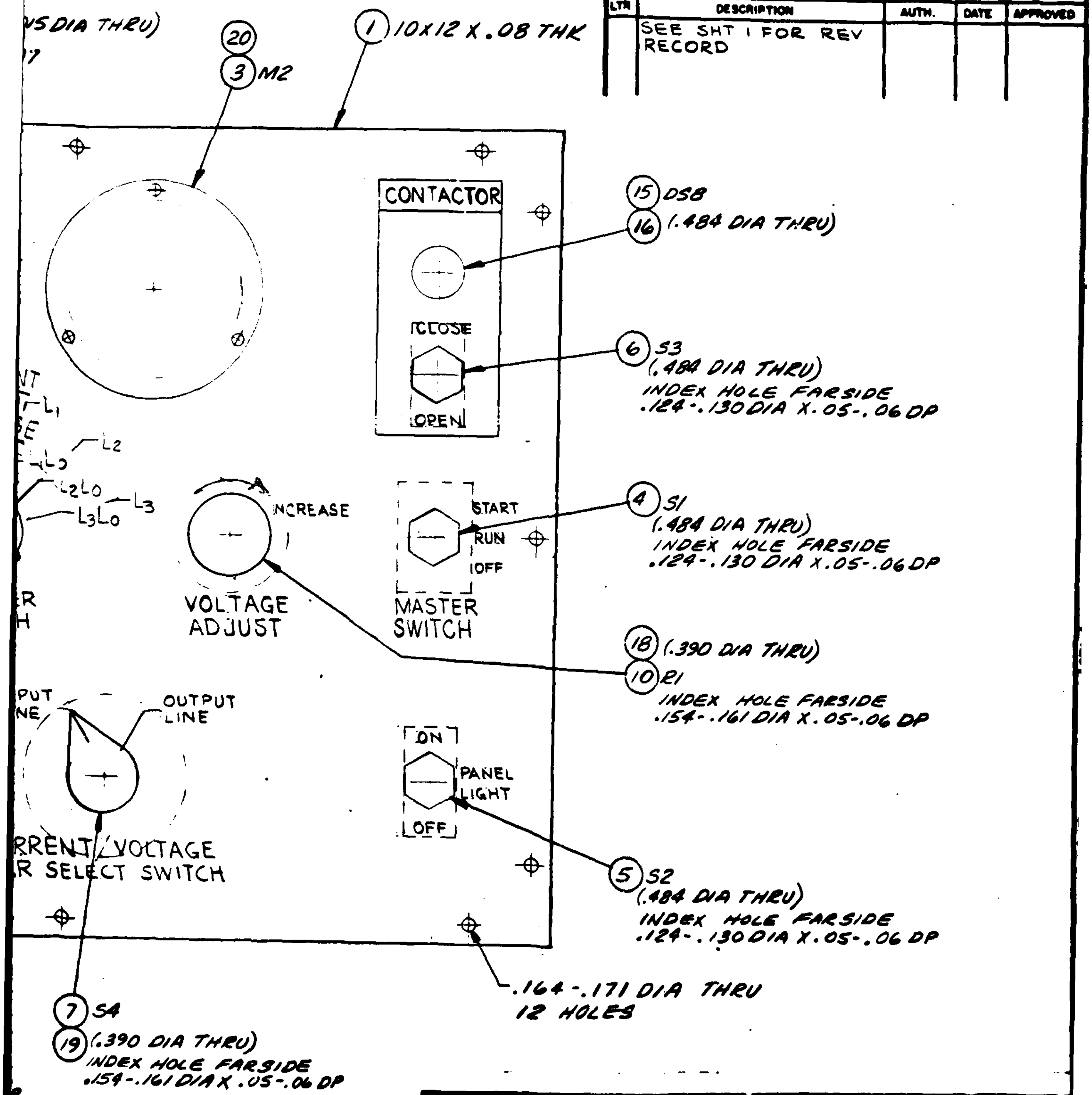
... CIRCUIT & POWER SUPPLY ASSYS

13160



20
2 M1
17 (1.015 DIA THRU)
14 DS7
2.188 DIA THRU
2 HOLES
.138-.144 DIA
THRU
6 HOLES
MALFUNCTION
INPUT
OVER VOLTAGE
UNDER VOLTAGE
OUTPUT
SHORT CIRCUIT
OVER LOAD
DS1 THRU 6 11
DS1 THRU 4 12
4 REQD 16
(.484 DIA THRU)
OUTPUT FREQUENCY
60 HZ
400 HZ
LAMP TEST/RESET
DS5 & DS6 13
2 REQD 16
(.484 DIA THRU)
CURRENT
VOLTAGE
L1
L2
L3
L3L1
L1L0
L2L3
L2L0
L1L2
L3L0
METER SWITCH
INPUT LINE
CURRENT/VOL
METER SELECT S
S5 8
(.484 DIA THRU)
INDEX HOLE FARSIDE
.124-.130 DIA THRU X
.05-.06 DP
S6 9
(.390 DIA THRU) 19
INDEX HOLE FARSIDE
.154-.161 DIA X .05-.06 DP
7 S4
19 (.390
INDEX
.154-.1

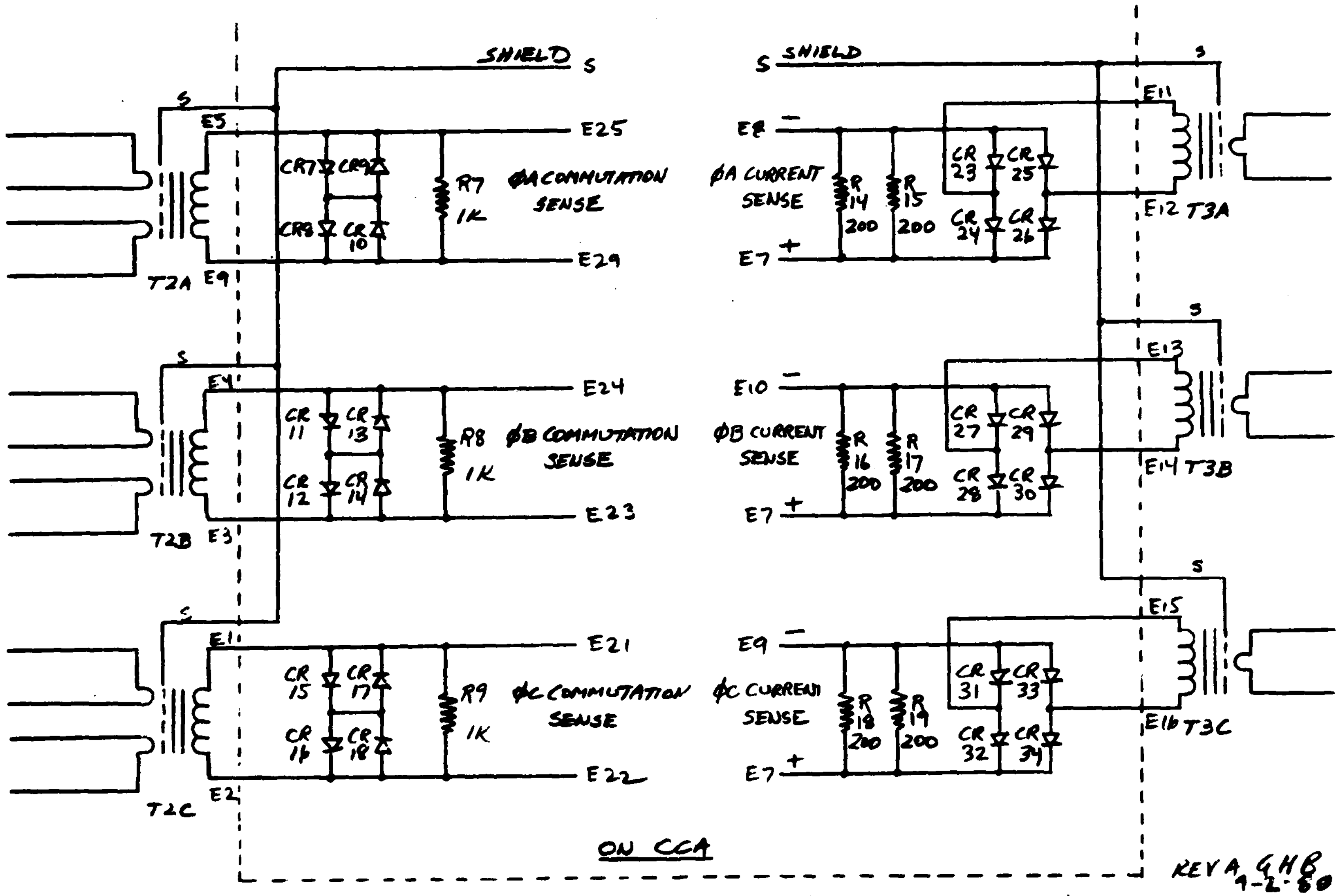
REVISIONS				
LTR	DESCRIPTION	AUTH.	DATE	APPROVED
	SEE SHT 1 FOR REV RECORD			



THE PART NUMBER IS THE DRAWING NUMBER AND THE DASH NUMBER THAT APPLIES

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± — 3 PLACE DECIMALS ± — ANGLES ± —	CONTR NO		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	DFTSMN/DSGR Kc:STUSAK	2-7-CT	TITLE PANEL, CONTROL ELECTRICAL COMPONENTS
	CHECKER		
MATERIAL SEE L/M	ENGR		
	APPD		
	APPD		SIZE C · CODE IDENT NO 13160 · DWG NO. SK002291 · REV +
	DSGN ACTIVITY APPD		
REF(AC-DRL) 306 · CHG CONTROL	OTHER APPROVAL		SCALE FULL · WEIGHT · SHEET 3

R82-127



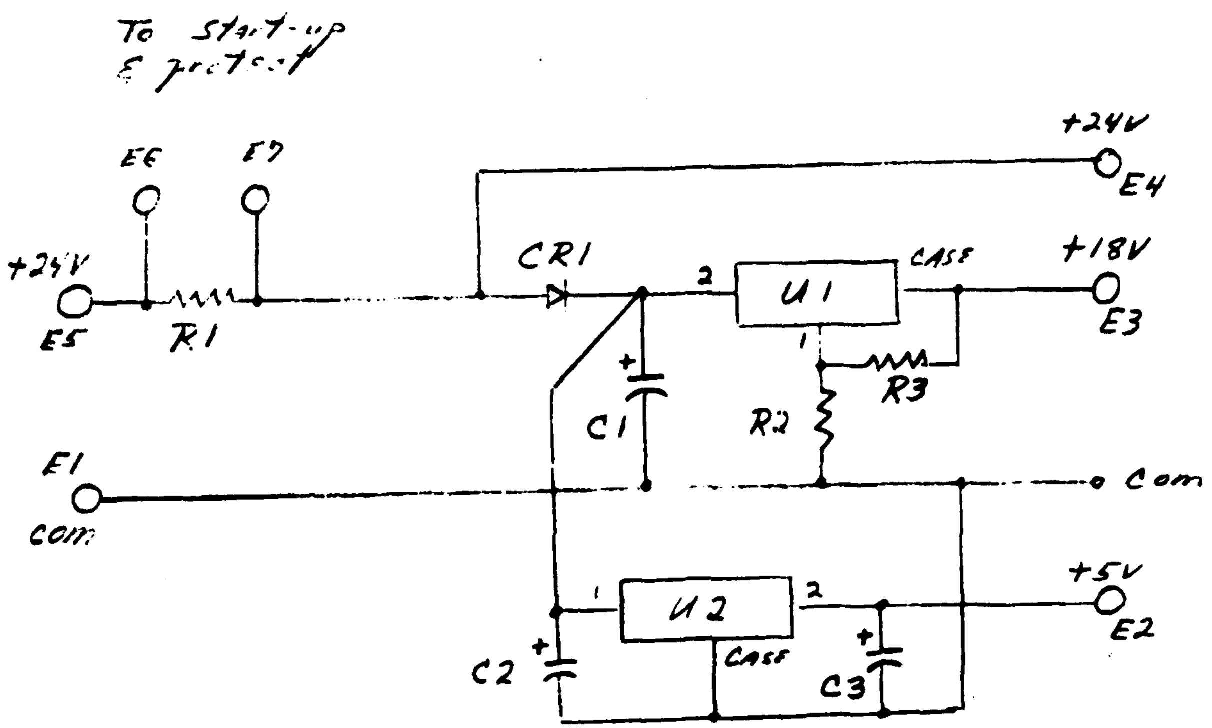
REV A GHB 9-2-80

Converter Sense CCA

SIZE	CODE IDENT NO.	DWG NO.	REV
A	13160	SK 002405	A
SCALE			

Converter Sense CCA

SIZE	CODE IDENT NO.	DWG NO.	REV
A	13160	SK 002405	A
SCALE		SHEET	



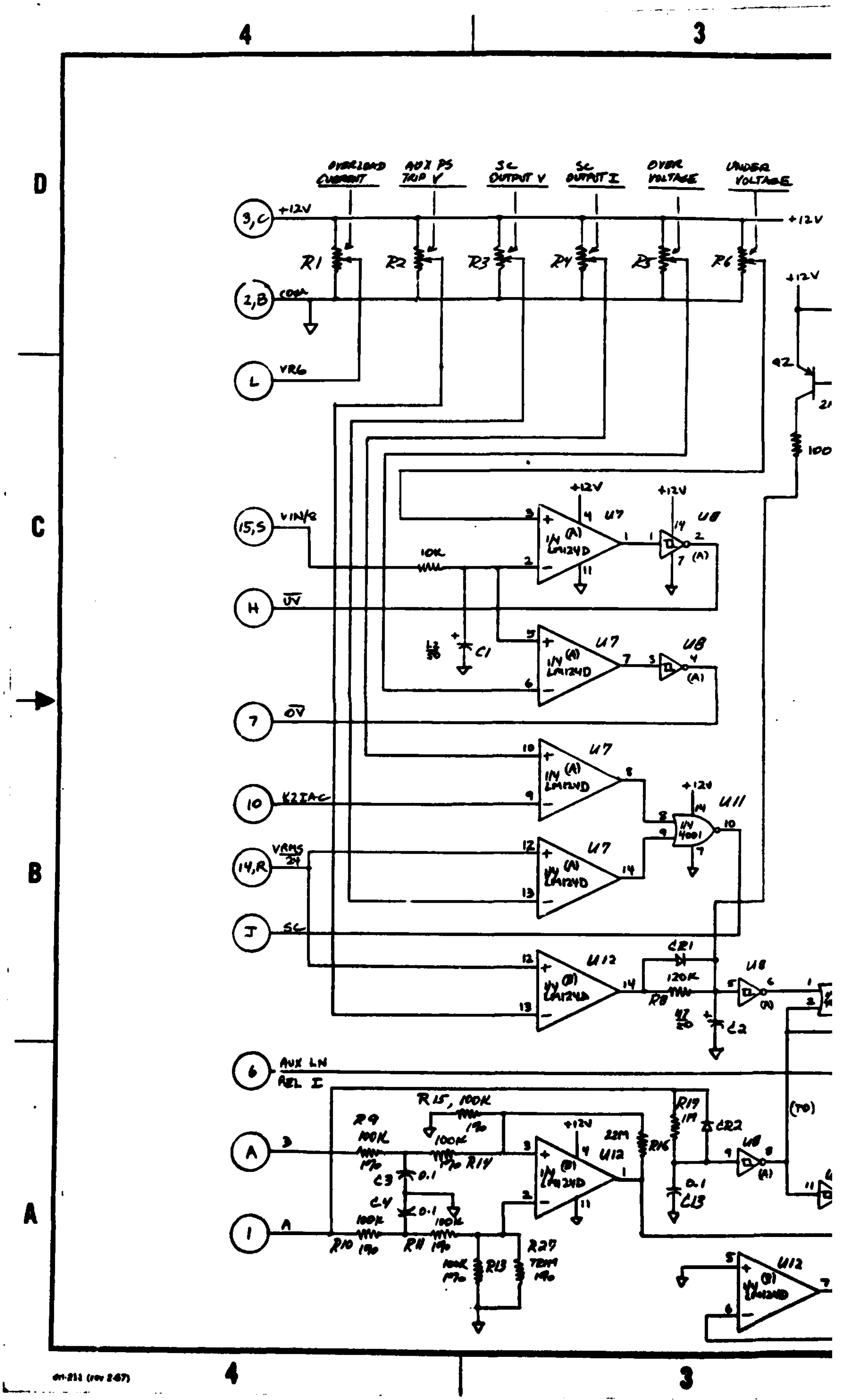
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIFORNIA

TITLE

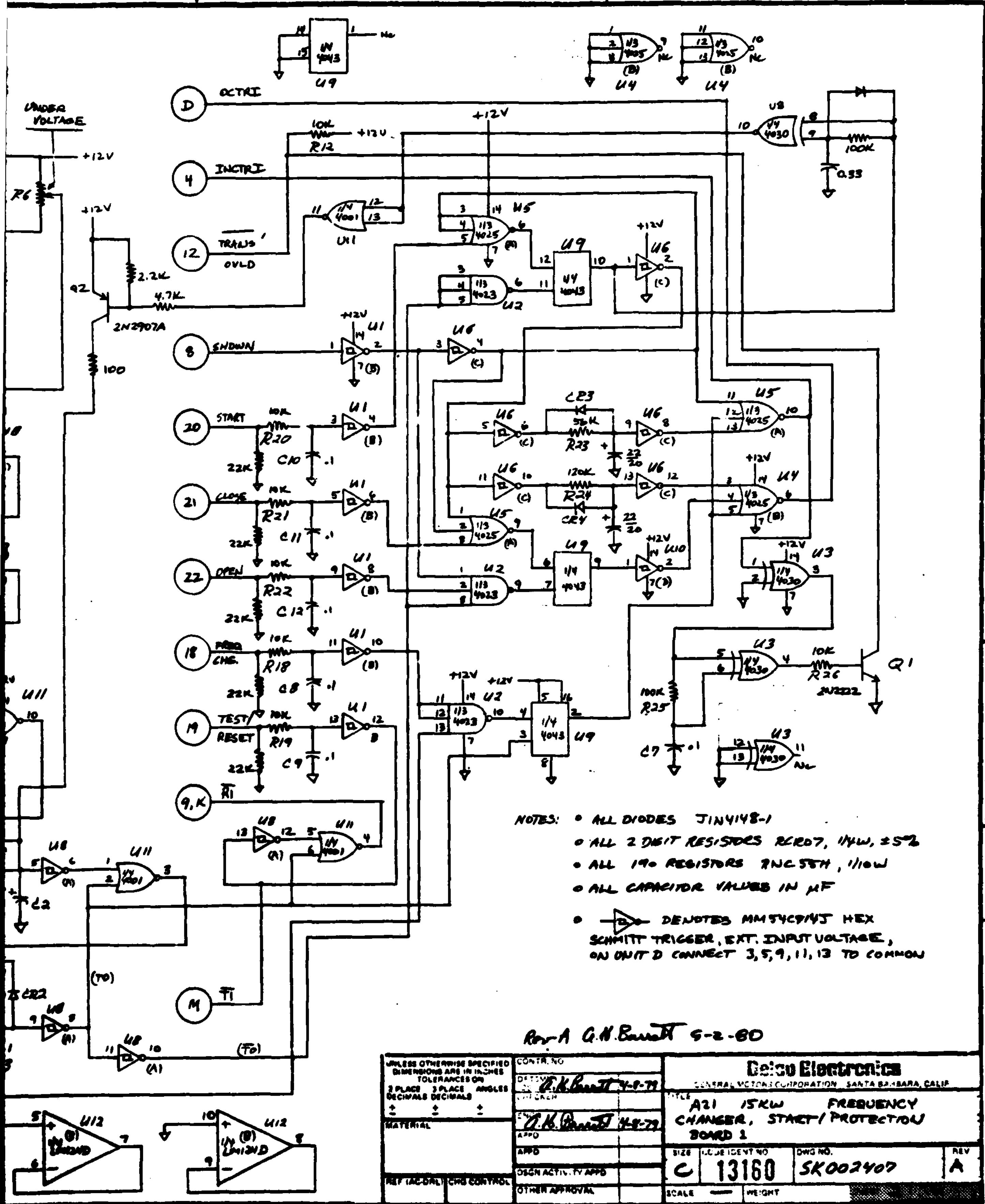
VOLTAGE REGULATOR

SIZE	CODE IDENT NO.	DWG NO.	REV
A	13160	SK002406	A

SBO-208 Rev 4/78



OVERLOAD CURRENT
AUX PS TRIP V
SC OUTPUT V
SC OUTPUT I
OVER VOLTAGE
UNDER VOLTAGE
+12V
COM
VRG
VIN/2
UV
OV
K2IAC
VRMS/24
SC
AUX LN
REL I
R1
R2
R3
R4
R5
R6
U7
U8
U11
U12
LM124D
4001
CR1
CR2
R8 120K
C1
C2
C3 0.1
C4 0.1
C13 0.1
R9 100K 1%
R10 100K 1%
R11 100K 1%
R13 100K 1%
R14 100K 1%
R15, 100K 1%
R16 22M
R17 1M
R27 TRIM 1%
10K
Q2
100
(TO)



NOTES:
- ALL DIODES JIN4148-1
- ALL 2 DIGIT RESISTORS RCR07, 1/4W, ±5%
- ALL 1% RESISTORS RNC55H, 1/10W
- ALL CAPACITOR VALUES IN µF
- ▷ DENOTES MM54C914J HEX SCHMITT TRIGGER, EXT. INPUT VOLTAGE, ON UNIT D CONNECT 3,5,9,11,13 TO COMMON

Rev-A G.N. Barrett 5-2-80

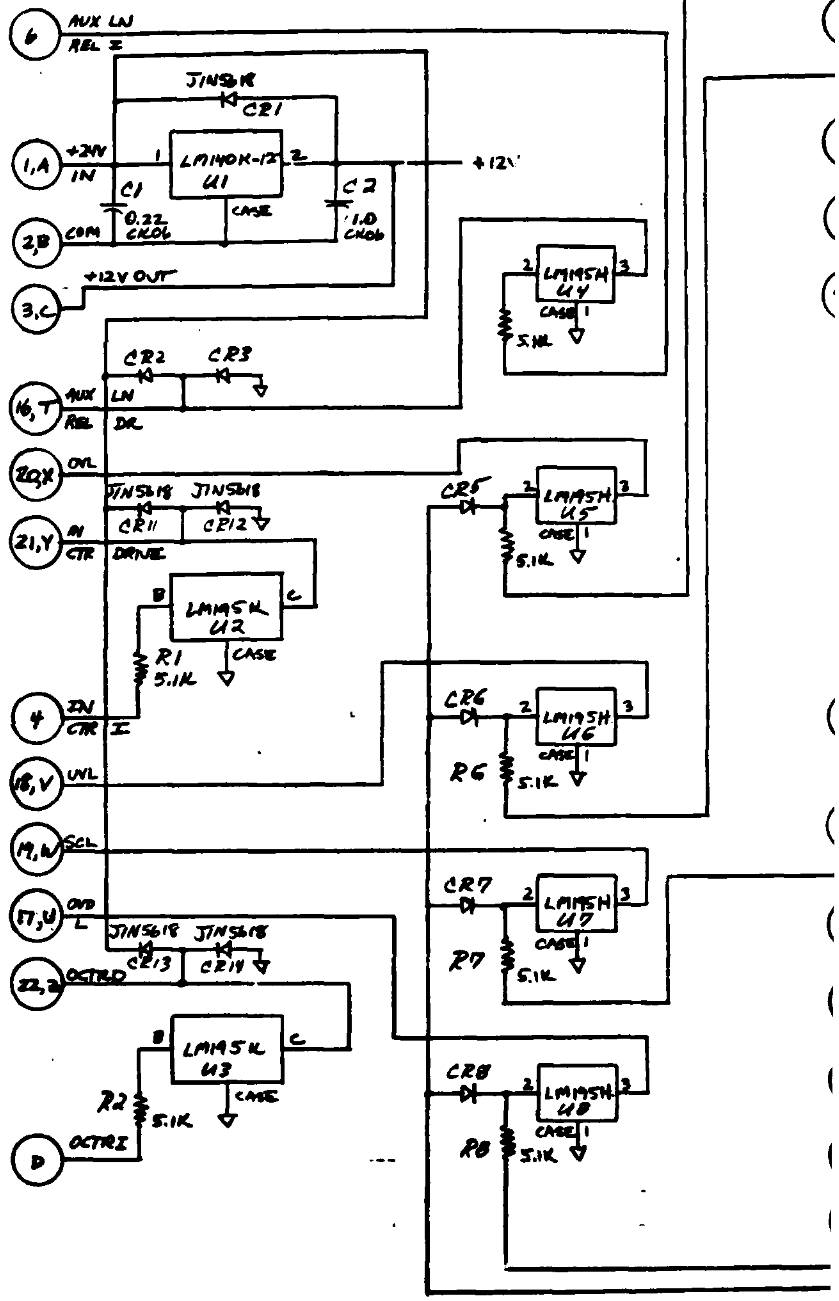
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO
MATERIAL	DRAWN G.N. Barrett 4-8-79
	ENGR G.N. Barrett 4-8-79
REF (AC ONLY) / CHG CONTROL	APPD / DSGN ACTIVITY APPD / OTHER APPROVAL

Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.

TITLE: A21 15KW FREQUENCY CHANGER, START/PROTECTION BOARD 1

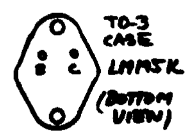
SIZE	CODE IDENT NO	DWG NO.	REV
C	13160	SK002407	A

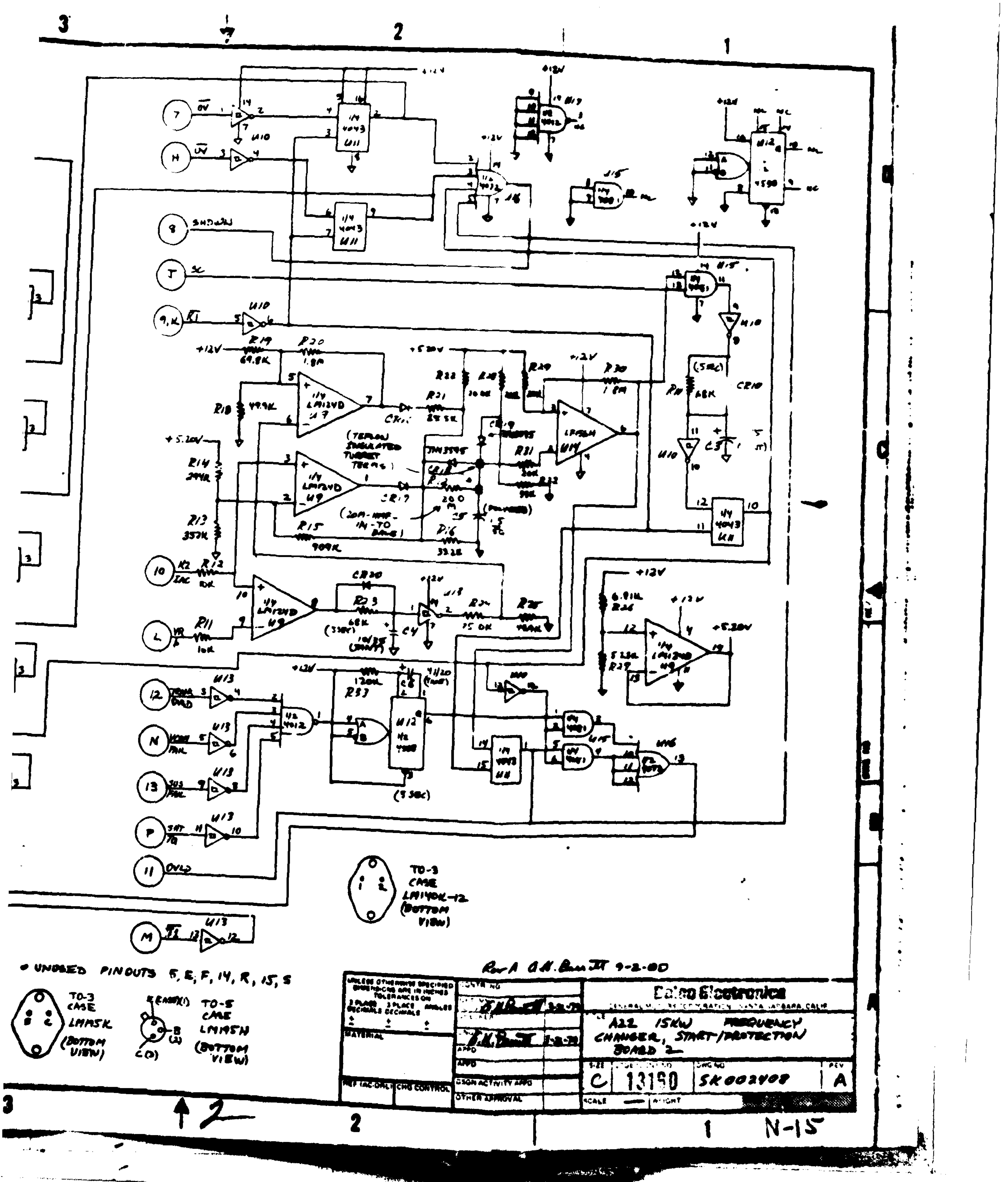
SCALE — WEIGHT



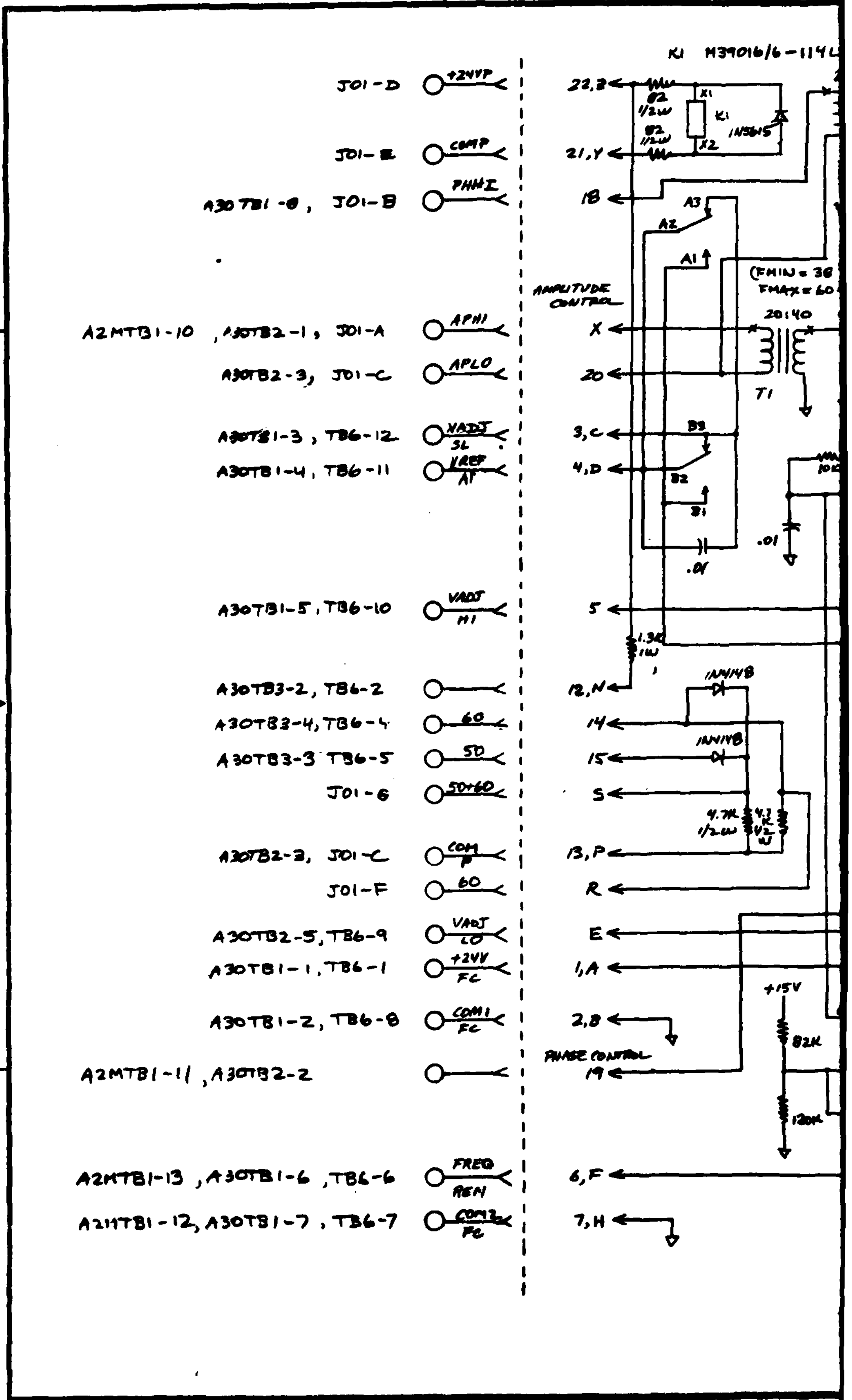
NOTES: • ALL DIODES JIN4148-1 UNLESS INDICATED
• ALL 2 DIGIT RESISTORS RCR07, 1/4W, ±5%
• ALL 3 DIGIT RESISTORS RNC55H, 1/10W, ±1%
• DENOTES MM54C914 J HEX SCHMITT TRIGGER, EXT. INPUT VOLTAGE
• ALL CAPACITOR VALUES IN µF

• UNUSED PIN

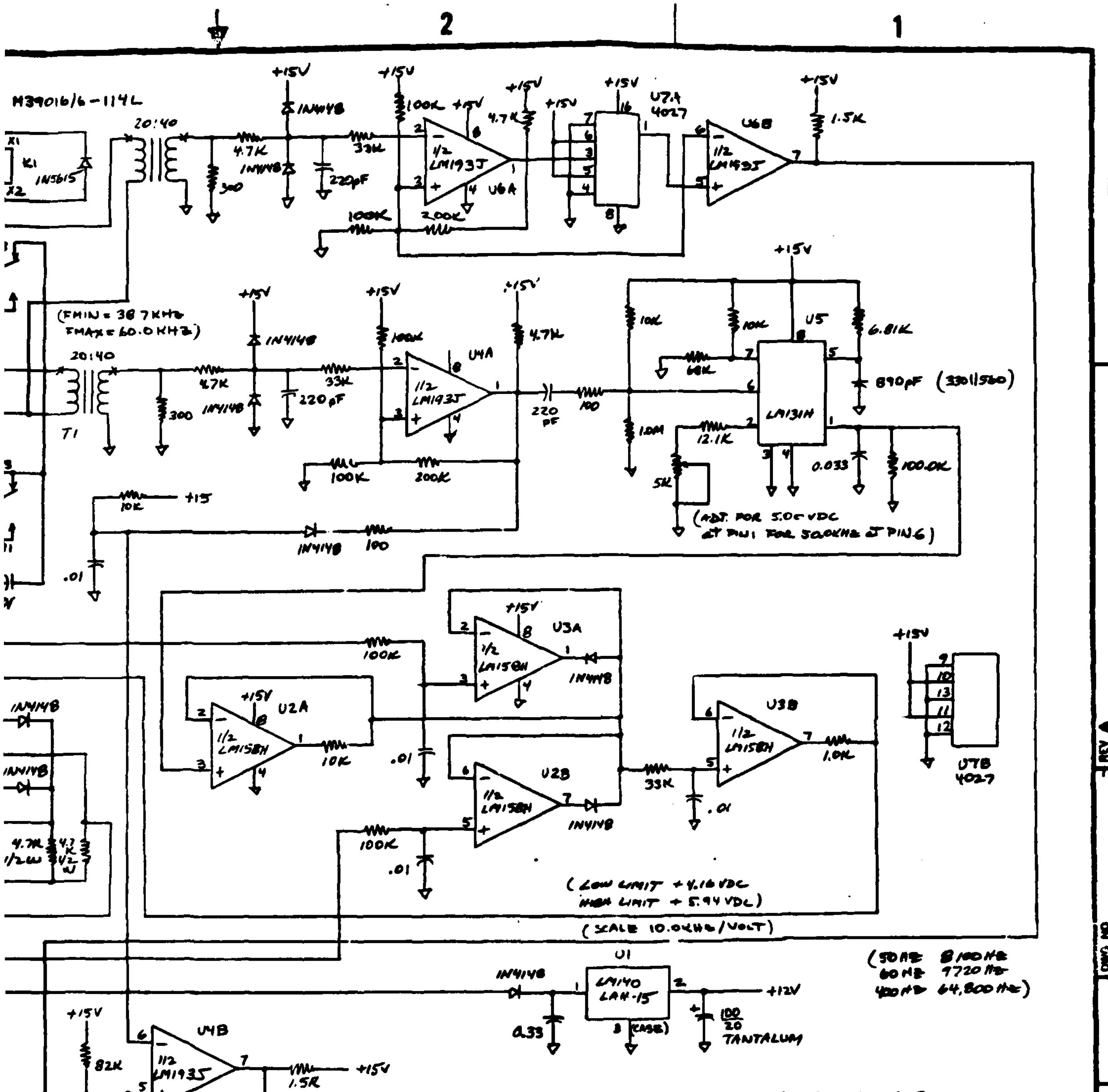




4043
U11
4012
4001
U15
U12
4538
SHDWN
LM124D
U9
LF356H
U14
R19
69.8K
R20
1.8M
R18
49.9K
R14
R13
357K
R15
909K
R12
10K
R11
R23
68K
R24
R25
R26
R27
R30
1.8M
R33
120K
C4
C3
(TEFLON INSULATED TURRET TERMS)
(5 SEC)
(3 SEC)
TO-3 CASE LM140K-12 (BOTTOM VIEW)
* UNUSED PINOUTS 5, E, F, 14, R, 15, S
TO-3 CASE LM117K (BOTTOM VIEW)
TO-5 CASE LM195H (BOTTOM VIEW)
Rev A 9-2-80
A22 15KW FREQUENCY CHANGER, START/PROTECTION BOARD 2
C
13190
SK002408
A
N-15



K1 M39016/6-114L
J01-D
+24VP
22,Z
82 1/2W
K1
1N5615
X2
J01-E
COMP
21,Y
A30TB1-8, J01-B
PHHI
18
A3
A2
A1
AMPLITUDE CONTROL
(FMIN = 36
FMAX = 60
A2MTB1-10, A30TB2-1, J01-A
APHI
X
20:40
A30TB2-3, J01-C
APLO
20
T1
A30TB1-3, TB6-12
VADJ SL
3,C
B3
A30TB1-4, TB6-11
VREF AI
4,D
B2
B1
.01
A30TB1-5, TB6-10
VADJ HI
5
1.3K 1W
1N4148
A30TB3-2, TB6-2
12,N
A30TB3-4, TB6-4
60
14
A30TB3-3 TB6-5
50
15
J01-G
50+60
S
4.7K 1/2W
A30TB2-3, J01-C
COM P
13,P
J01-F
60
R
A30TB2-5, TB6-9
VADJ LO
E
A30TB1-1, TB6-1
+24V FC
1,A
A30TB1-2, TB6-8
COM1 FC
2,B
PHASE CONTROL
A2MTB1-11, A30TB2-2
19
+15V
82K
120K
A2MTB1-13, A30TB1-6, TB6-6
FREQ REM
6,F
A2MTB1-12, A30TB1-7, TB6-7
COM2 FC
7,H



REV D G.H.B. 01-29-81
REV A G.H.B. 3-3-80
REV B G.H.B. 7-1-80
REV C G.H.B. 01-22-81

NOTES: A. ALL 2 DIGIT R'S RCR07, 3 DIGIT RNC55H
B. ALL CAPS CK05 OR CK06 CBR EXCEPT AS NOTED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS 3 PLACE DECIMALS ANGLES ± ± ±

MATERIAL

DFTSMN G.H.B. 1-78

CHECKER G.H. Barrett 1-78

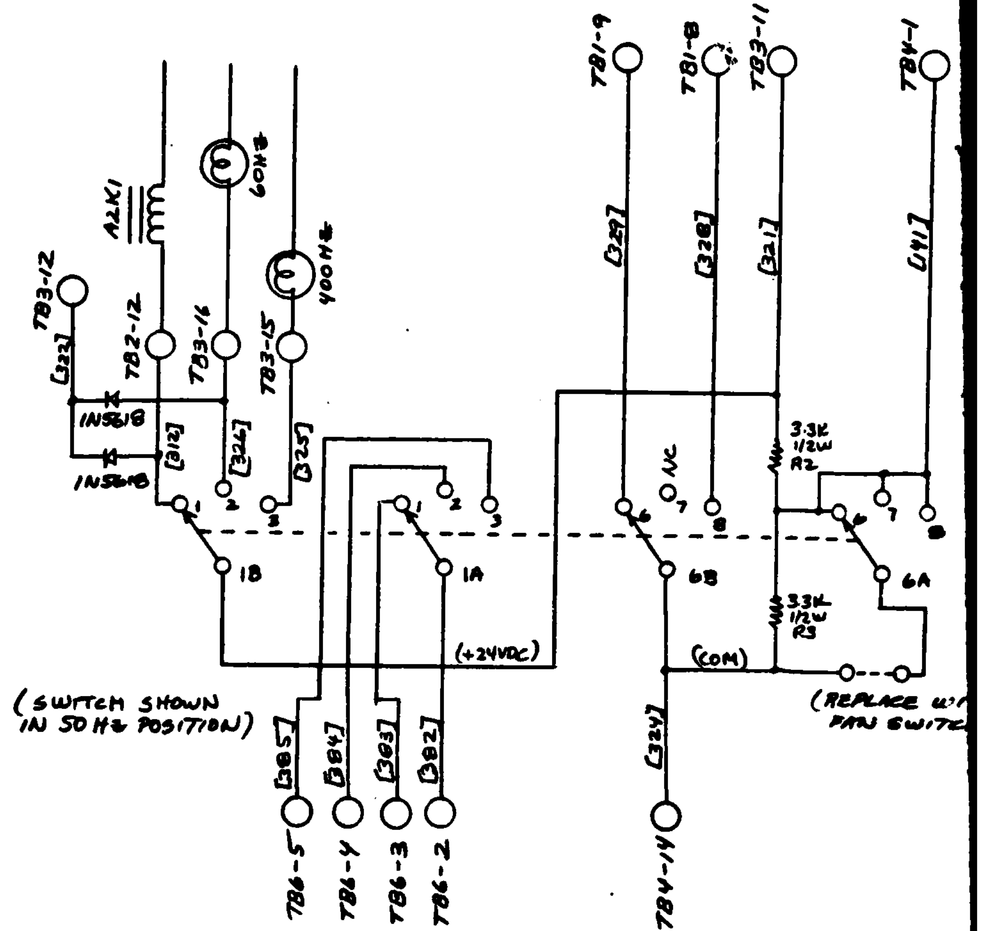
Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF.

TITLE 15KW FREQUENCY CHANGER PARALLELING CONTROL, CCA & INT. CON. A30

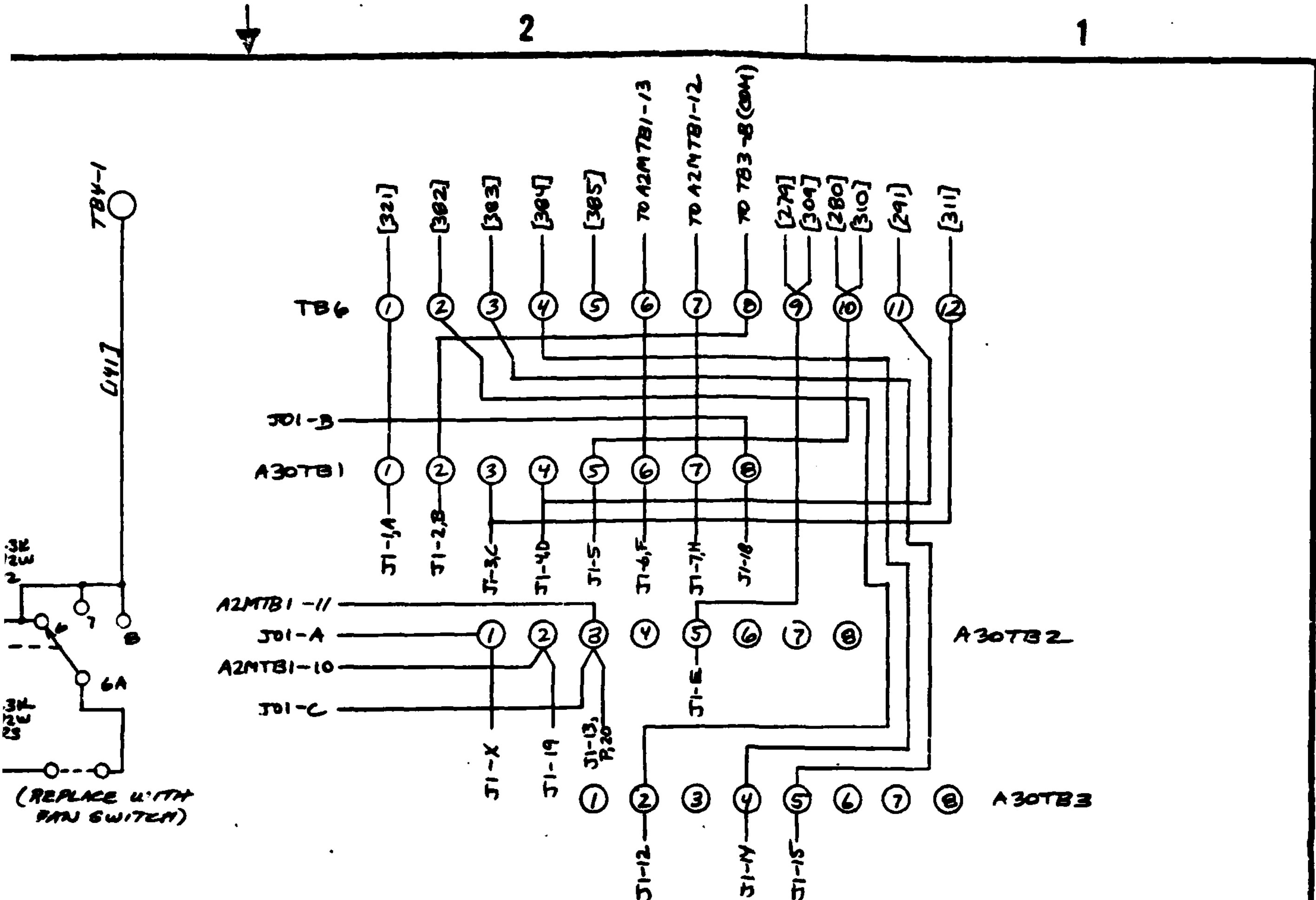
SIZE C | CODE IDENT NO 13160 | DWG NO SK002746 | REV D

SHEET 1 OF 1

N-16

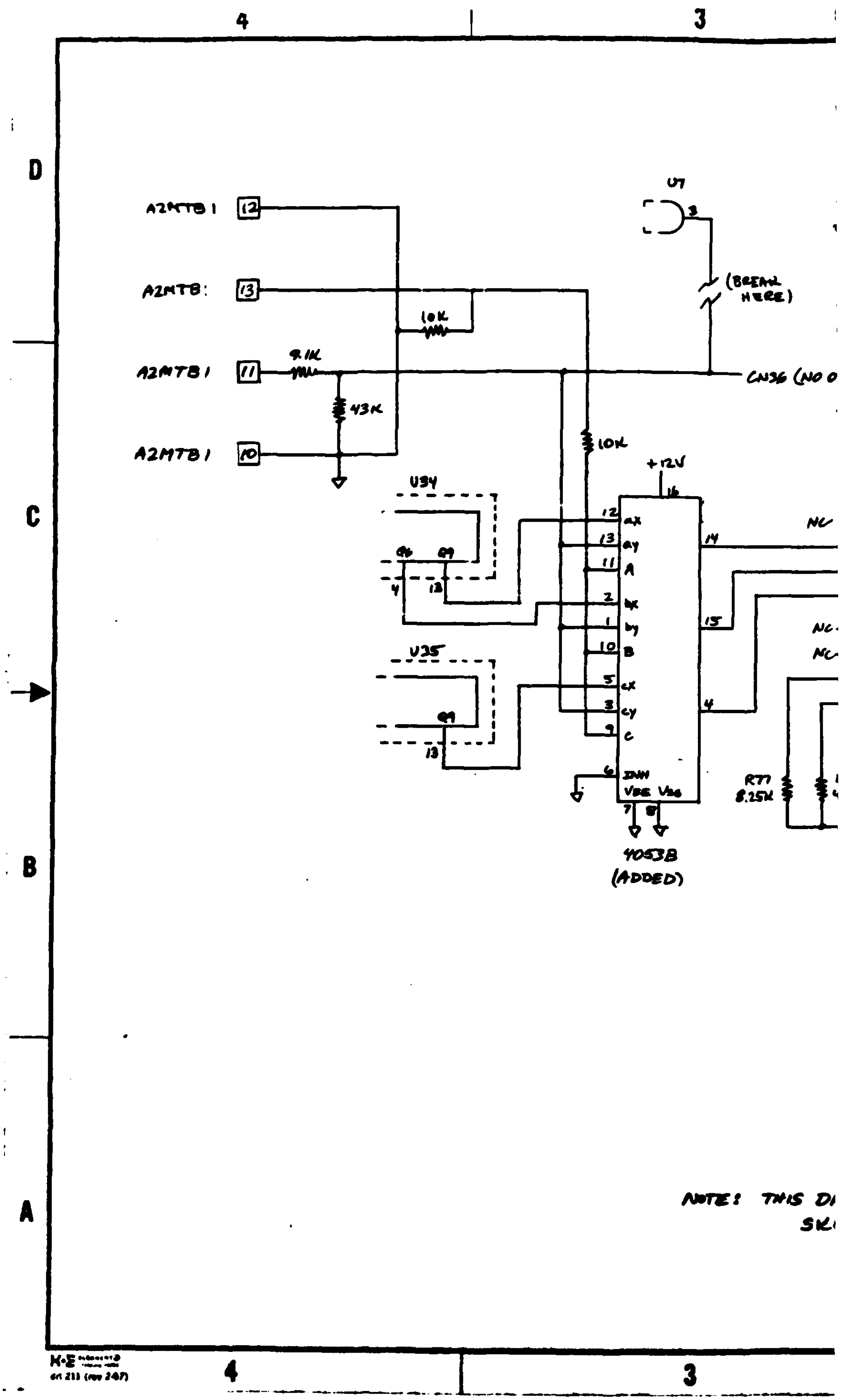


A2B FREQ SELECT



01-29-81 C.H.B. REV A

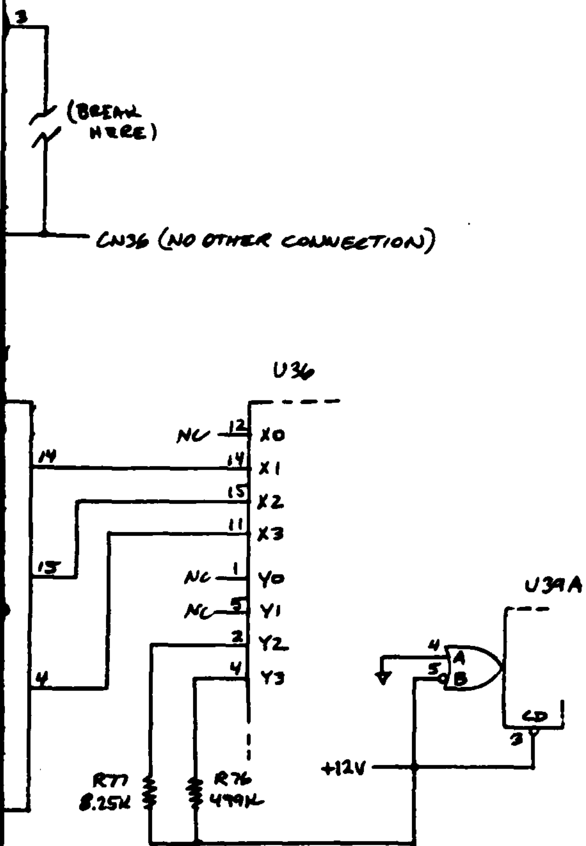
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	DETAIL DSGR C.H.B.	1-29-81	TITLE A28 MOD AND A30 INTERCONNECT
MATERIAL	CHECKER		
	ENGR		
	APPD		SIZE C / CODE IDENT NO. 13160 / DWG NO. SK002747 / REV A
REF (AC ORL) / CHG CONTROL	DSGN ACTIVITY APPD		
	OTHER APPROVAL		SCALE — / WEIGHT / SHEET 1 OF 1



A2MTB1
A2MTB:
A2MTB1
A2MTB1
12
13
11
10
10K
9.1K
43K
10K
U7
(BREAK HERE)
CN36 (NO O
+12V
U34
U35
4053B (ADDED)
R77 8.25K
NC
NOTE: THIS DI
SK

K+E

3 2 1

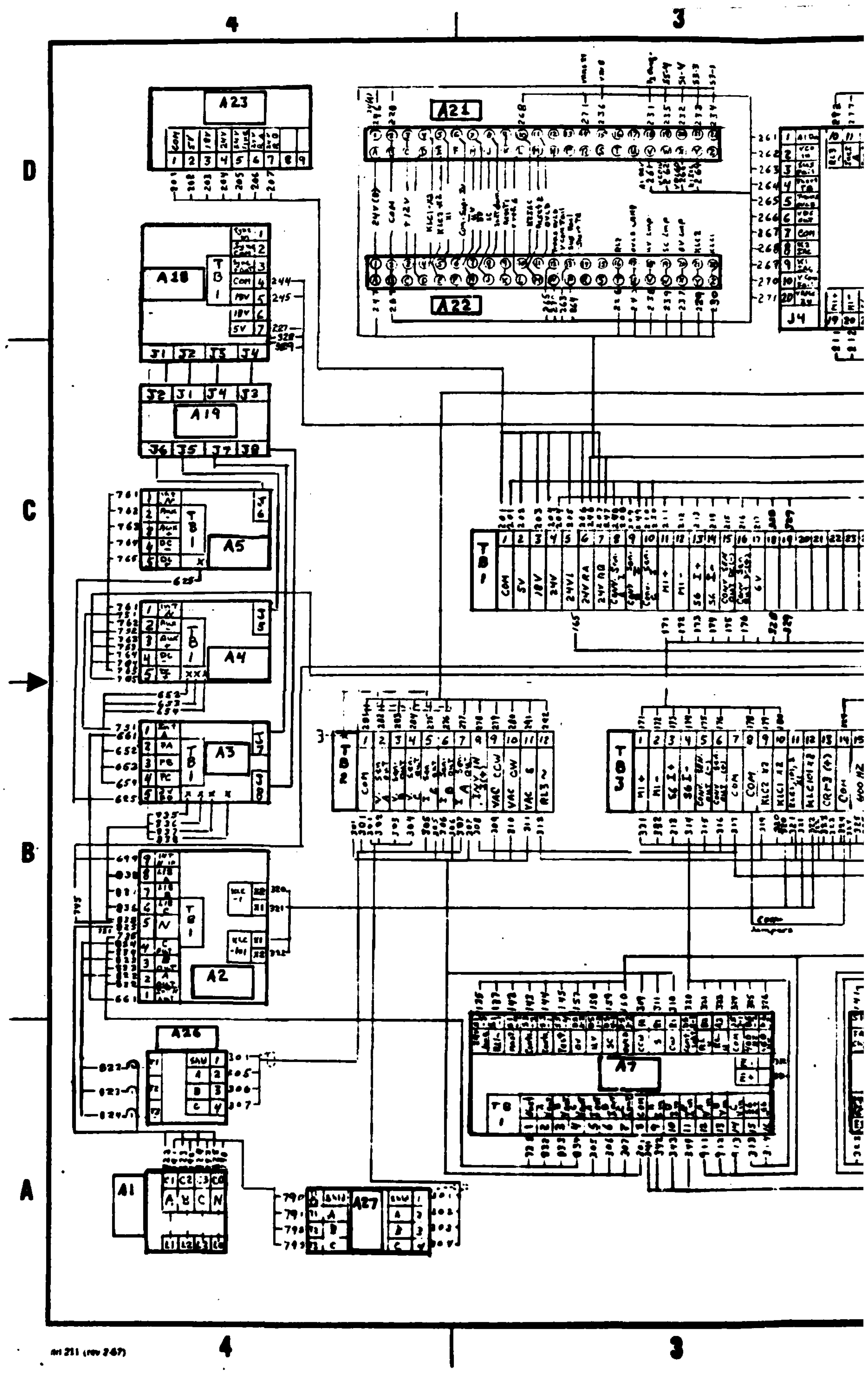


01-29-81 G.N.B. REV A

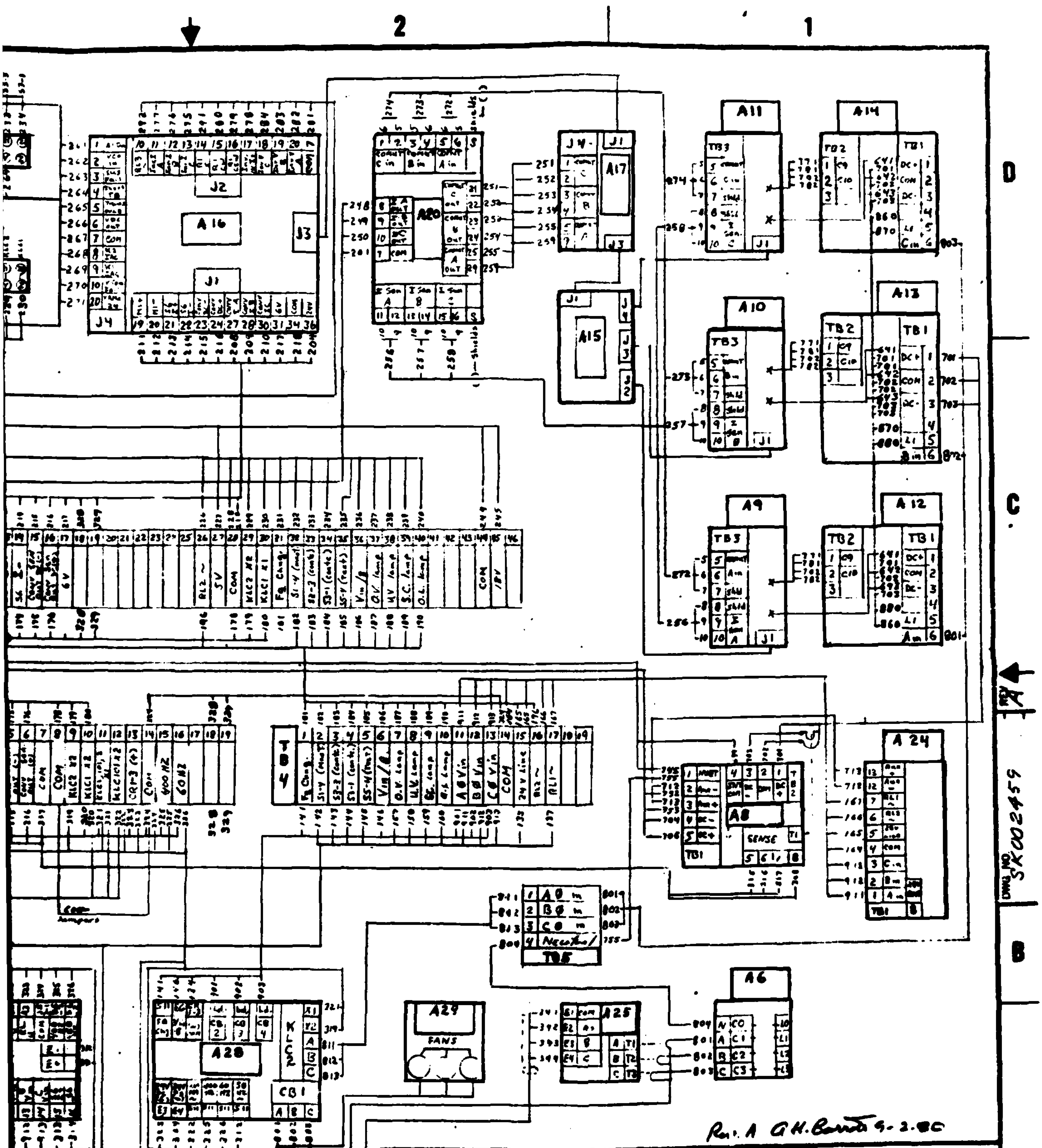
NOTE: THIS DRAWING SUPPLEMENTS SK002211

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR NO		Delco Electronics GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF
	DFTSMN G.N.B.	2/14/81	TITLE A2M MODIFICATIONS FOR EXT. FREQ. SOURCE
MATERIAL	CHECKER		
	ENGR		
	APPD		
	APPD		SIZE C / CODE IDENT NO 13160 / DWG NO. SK002748 / REV A
NEXT ASSY / USED ON / CHG CONTROL	DSGN ACTIVITY APPD		
	OTHER APPROVAL		SCALE —— WEIGHT SHEET 1 OF 1

3 2 2 1



4
3
D
C
B
A
A23
A21
A22
A18
A19
A5
A4
A3
A2
A26
A1
A27
A7
J4



Rev. A G.H.Barnes 9-2-80

A30 NOT SHOWN

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON 2 PLACE DECIMALS ± 3 PLACE DECIMALS ± ANGLES ±	CONTR. NO.
	DFTSMN J. Walls 6/79
	CHECKER
MATERIAL	ENGR ZFB 6/79
	APPD
	APPD
	DSGN ACTIVITY APPD
REF (ACONLY) D06 / DWG CONTROL	OTHER APPROVAL

Delco Electronics
GENERAL MOTORS CORPORATION SANTA BARBARA, CALIF

TITLE 15 KW FREQUENCY CHANGER WIRE/INTERCONNECT DIAGRAM

SIZE	CODE IDENT NO.	DWG NO	REV
C	13160	SK002459	A

SCALE — WEIGHT SHEET 1 OF 1

2 1

N-19

DATE
ILMED
-8